Frank Laboratory of Neutron Physics
Division of Nuclear Physics

SEMINAR

Leader – V.N. Shvetsov

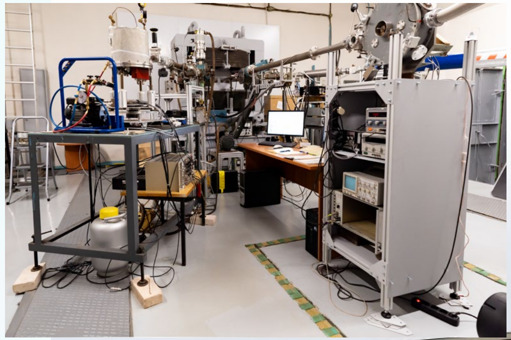
October 16 (Wednesday), 11:00
FLNP Conference Hall (3d floor)

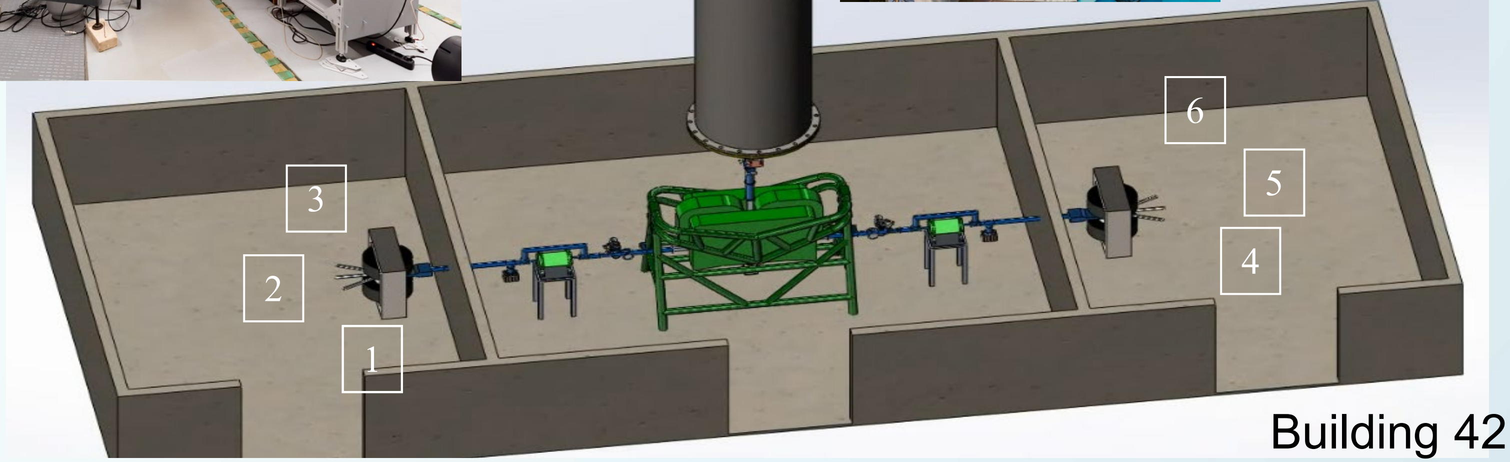
Basic and applied research at the EG-5 accelerator of JINR (Dubna, Russia) and 5.5-MV Van de Graaff accelerator in Mexico in terms of development of international cooperation

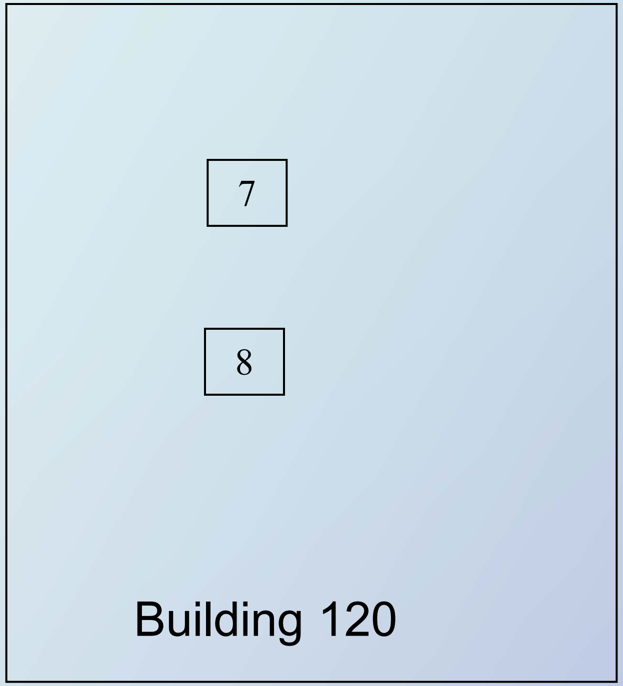
A.S. Doroshkevich[1], I.A. Chepurchenko[1] **Prof. Efrain Rafael Chavez Lomeli**[2,3]
[1] Frank Laboratory of Neutron Physics, JINR, Dubna
[2] Institute of Physics, National Autonomous University of Mexico
[3] Flerov Laboratory of Nuclear Reactions, JINR, Dubna

Dubna
2024

EG-5 accelerator complex







1 –Installation for ion implantation of silicon plates "DNEPR" (JSC "Micron");

2 – Ion beam spectrometer module, including atmospheric * and PIGE;

3 – Neutron-induced particle emission research facility / Radiation treatment chamber;

4 – Positron annihilation method*;

5 – Channeling method*;

6 – Nuclear microprobe*;

7 – Chemical Laboratory;

8 – Engineering laboratory *;

*- will be after modernization

9 – Spectral ellipsometer;

10 – Impedance Meter;

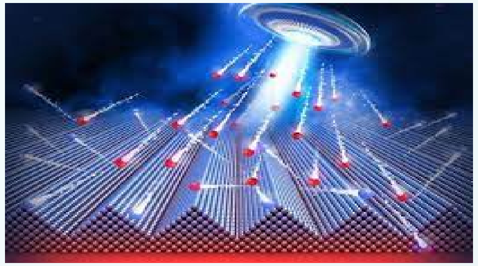
11 – Potentiostat;

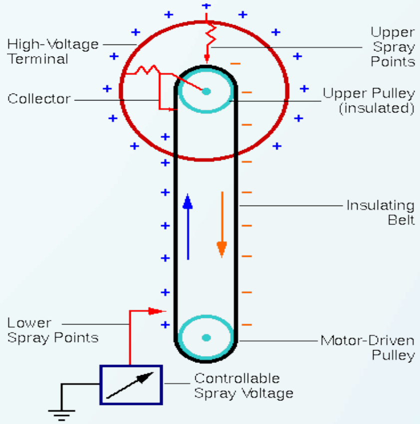
12 – Optical microscopes.

Electrostatic accelerator EG-5

Significant advantage

- high energy stability of ion beam;
- high intensity of ion beam;
- accelerated particles (H^+, He^+, D^+);
- accelerated voltage (from 1,1 MeV to 3,5MeV);
- possibility of obtaining of high-intensity ion beams.





Areas of use

- Nuclear reactions with fast quasimonoenergetic neutrons;
- Ion Beam Spectrometry (Multilayer structures, isotope determination, elemental depth profiling);
- Radiation technologies (Science, technology, medicine, etc.).

Ion beam parameters

- Range of ion beam currents - 0,01 - 30 мкА (100 – 150mkA*);
- Ion beam energy range – 1,1 – 3,5MeV (4,1 MeV*);
- Energy resolution (H^+, He^{2+}) - not worse than 15keV;
- Charged particles flow (H^+, He^{2+}) – 10^{12}–10^{13} part /s sm^{-2};
- Neutrons flow – 5 10^7 pat/s sm^2;
- Neutrons energy -20 – 800keV; 3,5 - 5,1MeV ±0,1 MeV.

*- will be after modernization

A set of complementary methods for the study of surface layers of materials

Remote control

- Ellipsometer (optical and electronic features),
- Impedance meter and
- Potentiostat (electrical properties),
- Microweights,
- Optical microscope,
- General laboratory equipment.

Comprehensive study of physical properties and elemental composition of multilayer structures for optics, electronics, materials science.

CNFMSIN - Sector DNF FLNP

Sector staff: 24 employees:

5 - Directorate staff;

11 – Technical staff;

10 – Scientific staff;

2 – Doctor of science;

3 - PhD;

4 – Students (bachelors / masters);

5 – Postgraduates;

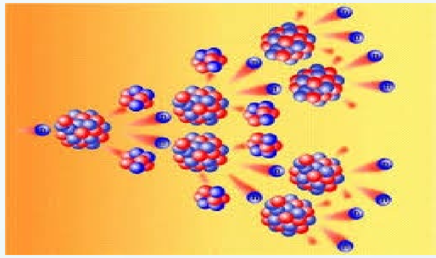
2 – Undergraduates;

The average age is 43.

Scientific program

Based on the JINR PTP, there are three main directions that *we plan to develop* using an electrostatic accelerator

1. Nuclear physics. The study of the properties of excited nuclei, reactions with the emission of charged particles, fission physics, obtaining relevant data for astrophysics, nuclear energy and the problem of transmutation of nuclear waste using neutron- and gamma-induced reactions.



(n,α)

Reactions

(n,f)

2. Condensed matter physics. Application of neutron physics methods in different fields of science and technology:

- Radiation material science;
- Radiobiology;
- Nuclear medicine;
- Solid state Physics.

3. Applied and methodical research.

Nuclear physics

Nuclear reactions with fast quasimonoenergetic neutrons, including:

- research of fast neutron fission: measurements of the **prompt fission neutron (PFN) spectra and total kinetic energies (TKE) in reactions** ^{235}U(n,f), ^{238}U(n,f), ^{237}Np(n,f), ^{239}Pu(n,f) in the range of neutron energies 1-5 MeV/core;

- **study of the multiplicity of PFNs in these fast neutron reactions** in geometry with high efficiency of **PFN** registration;

- measurement of the **spectra of charged particles from the reactions (n, α), (n, p)** depending on the neutron energy in the range of up to 5 MeV and higher;

- measurement of the **integral and differential cross sections** of these reactions depending on the neutron energy;

- study of the **spectrum and angular distributions of charged particles** at a neutron energy of ~ 20 MeV aimed at investigating non-statistical effects;

- investigation of reactions (α, n) and (p, n) in combination, respectively, with reactions (n, α) and (n, p);

- study of **elastic and inelastic scattering of fast neutrons** on atomic nuclei;

- using the **TOF technique** in a pulsed accelerator mode (f~ 1 MHz, dt~1-10 ns).

Scientific activity of the sector

EG-5 Accelerator staff activityes

Industrial Partners 2024

1. *JSC Mikron.*
2. *JSC Angstrem*
3. *State Corporation "ROSATOM"*

mikron ангстрем ROSATOM

Formal results 2024

- 5 ranked (Q1, Q2) publications;
- 19 publications;
- 11 oral reports

2019 - 2024

- 35 (Q1, Q2) publications;
- 126 publications;
- 205 reports

Scientific cooperation intensified

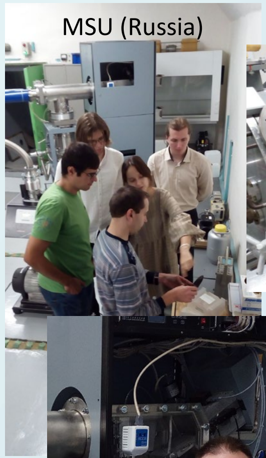
Scientific cooperation

12 countries;
7 projects;
26 cooperation agreements;
3 industrial partners, including a major electronics manufacturer (Mikron JSC) and the State Corporation ROSATOM.
Latin America, Africa and Middle East countries were added: Cuba and Mexico, Egypt, Turkey.

EDM-24

Scientific projects within the framework of cooperation programs JINR - Republic of Serbia; JINR - Republic of Belarus, etc.

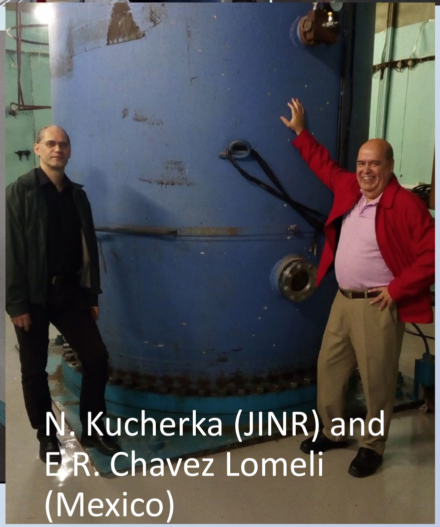
MSU (Russia)



Cuba

R. Balvanovich (Serbia)

Prof. Lagov P.B. NRNU MEPhI



N. Kucherka (JINR) and E.R. Chavez Lomeli (Mexico)

Collaboration within JINR

1. *National University of Uzbekistan, Tashkent, Uzbekistan (Additional agreement N1k from 07.10.2022 to 07.10.2027);*
2. *Donetsk Galkin Institute of Physics and Technology, No. 140;*
3. *JSC "SNIP" (Rosatom State Corporation) No. 231 until 12/31/2026;*
4. *Institute of Radiation Problems, Ministry of Science and Education of the Republic of Azerbaijan No.410, until 12/31/2028 ;*
5. *Frumkin Institute of Physical Chemistry and Electrochemistry of the Russian Academy of Sciences, RF, No. 271 until 12/31/2026;*
6. *Kyzylorda University named after Korkyt Ata, Kazakhstan, No.286, until 12/31/2026 ;*
7. *Bandirma Onyedi Eylul University Turkey No.409, until 12/31/2026 ;*
8. *University of Novi Sad, Faculty of Technology of Novi Sad and University of Belgrade, Vinca Institute of Nuclear Sciences No.289 until 01.01.2031;*
9. *Institute of General and Inorganic Chemistry of the National Academy of Sciences of Belarus No. 408, until 12/31/2028 ;*
10. *NAO "Karaganda Industrial University" No. 336, until 01.01.2026 ;*
11. *" Federal State Budgetary Institution "All-Russian Scientific Research Institute of Forest Genetics, Breeding and Biotechnology" No. 356, until 12/31/2026;*
12. *Kazakh Research Institute of Management named after I.Zhakhaev (4964-4-21/22) NUST – MISIS, RF, No.233, until 30.06.2024 ;*
13. *Budker Institute of Nuclear Physics SB RAS;*
14. *Ural Federal University named after the first President of Russia B.N. Yeltsin No. 415, until 12/31/2028 ;*
15. *Institute of Materials Science of NPO "Physics-the Sun" of the Academy of Sciences of Uzbekistan, Tashkent, No.232, until 12/31/2026*
16. *Institute of Materials Science of NPO "Physics-the Sun" of the Academy of Sciences of the Republic of Uzbekistan*
17. *Federal State Educational Institution "Dubna University" No. 404, until 01.01.2031*
18. *Litvinenko Institute of Physical and Organic Chemistry and Carbon Chemistry No.314, until 12/31/2031*
19. *University of Havana (Cuba) No.379 until 12/31/2026*
20. *JSC "Micron" No.160 until 12/31/2030*
21. *JSC ANGSTROM JSC No. 13.02.23/01 to 12/31/2030*
22. *BSU (Minsk, Belarus);*
23. *Joint Institute of Solid State Physics and Semiconductors of the National Academy of Sciences of Belarus, Minsk, Belarus.*

External collaboration

European Commission

HORIZON 2020

The EU Framework Programme for Research and Innovation

From 2019 to 2024, 27 international projects were implemented, including HORIZON 2020 program project

Nanotechcenter

UIB Universitat de les Illes Balears

THE MINISTRY OF TRANSPORT, COMMUNICATIONS AND HIGH TECHNOLOGIES OF THE REPUBLIC OF AZERBAIJAN

FCT FACULDADE DE CIÊNCIAS E TECNOLOGIA UNIVERSIDADE NOVA DE LISBOA

Departamento de Química

NOVA id FCT Associação para a Inovação e Desenvolvimento da FCT

BLUEORIZON

Publications Q1-Q2 in 2024

1. Nguyen Thi Bao My , Trinh Thi Thu My, Inga Zinicovscaia, Le Hong Khiem,· Konstantin Vergel, **Phan Luong Tuan**, Ha Lan Anh,·Nguyen Thi Thu Ha. Modeling of the Arsenic Uptake by Brassica perviridis (L. H. Bailey) (Spinach Mustard) Growing on Diferent Soils Collected in Northern Vietnam // Water Air Soil Pollut (2024) 235:180 https://doi.org/10.1007/s11270-024-06989-7 **(Q2, IF=3,8)**
2. Carmen Mita, Mariana Frenti, Nicoleta Cornei, Georgiana Bulai, Marius Dobromir, **Alexandr Doroshkevich, Zhanna V. Mezentseva**, Diana Mardare High stability and photocatalytic activity of N-doped ZrO_2 thin films // Journal of Alloys and Compounds Available online 13 June 2024, 175134. https://doi.org/10.1016/j.jallcom.2024.175134 **(Q1, IF=6,37)**
3. Polyakov A.Y., Vasilev A.A., Kochkova A.I., Shchemerov I.V., Yakimov E.B., Miakonkikh A.V., Chernykh A.V., Lagov P.B., Pavlov Y.S., **Doroshkevich A.S., Isaev R.S.,** Romanov A.A., Alexanyan L.A., Matros N., Azarov A., Kuznetsov, A., &Pearton, S. (2024). Proton damage effects in double polymorph γ/β-Ga_2O_3 diodes. Journal of Materials Chemistry C, 12(3), 1020–1029.https://doi.org/10.1039/D3TC04171A**(Q1, IF – 5.7).**
4. Dobromir, **Alexandr Doroshkevich,** and Abdullah Yildiz. 2024. "Electrical Conduction Mechanism of Mg-Doped ZrO_2 Thin Films" Materials 17, no. 15: 3652. https://doi.org/10.3390/ma17153652**(Q2, IF – 3.1).**
5. **A.V. Maletskii,** G.K. Volkova, D.R. Belichko, V.A. Glazunova, A.S. Doroshkevich, A.A. Tatarinova, S.I. Lyubchyk, S.B. Lyubchyk Influence of stabilized zirconium dioxide and high hydrostatic pressure on the kinetics of sintering nanopowders of metastable aluminum oxide // Ceramics International 2024, https://doi.org/10.1016/j.ceramint.2024.09.002 **(Q1, IF=5,1).**

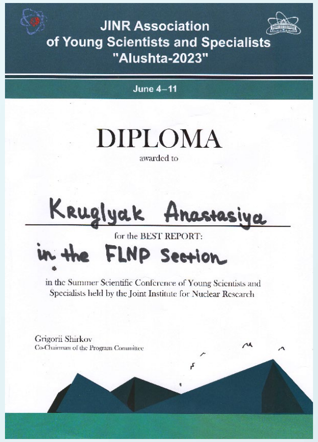
Patents

1. Rospatent No.2019135580 (070225) "Solid-state capacitor-ionistor with a dielectric layer of dielectric nanopowder" Authors Doroshkevich A.S., Shilo A.V., Zelenyak T.Yu., Konstantinova T.E., Lyubchik A.V., Tatarinova A.A., Gridina E.A., Doroshkevich N.V. Patent holder: JINR. Application No. 2019135580; priority of the invention 5.11.2019; Date of registration in the State Register of Inventions of the Russian Federation 13.09.2020, the validity period of the exclusive right is 2039.
2. PCT - patent WO 2021/10/107909 A1 from 03.06.2021 CHEMOELECTRONIC CONVERTER BASED ON ZrO_2-3mol%Y_2O_3 NANOPOWDERS", applicant LIMITED LIABILITY COMPANY "NANOTECHCENTER", Ukraine Authors: Shylo Artem, Doroshkevich Oleksandr, Zelenyak Tatyana, Konstantinova Tetyana, Lyubchyk Svitlana, Lyubchyk Sergiy, Lyubchyk Andriy, Lygina Olena. Patent Application Number No.PCT/UA2019/000147 (26.11.2019).
3. Isaev R.Sh., Dzhumaev P.S., Leontieva-Smirnova M.V., Naumenko I.A. "Method of electrodeposition of chromium-molybdenum coating on the inner surface of thin-walled pipes made of chromium steel" // Application for Patent of Russia No.2023125747.

Independent research premises

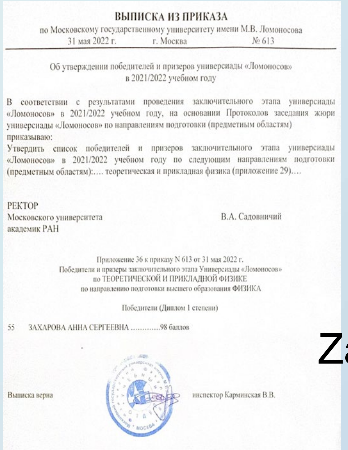
Maletsky A.V.

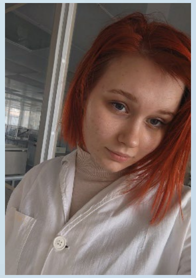
2024



Kruglyak A.I.

2023

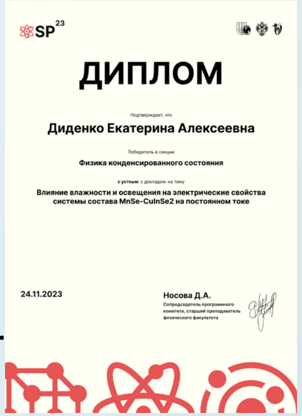




Zakharova A.S.

2022

Диденко Е.А.



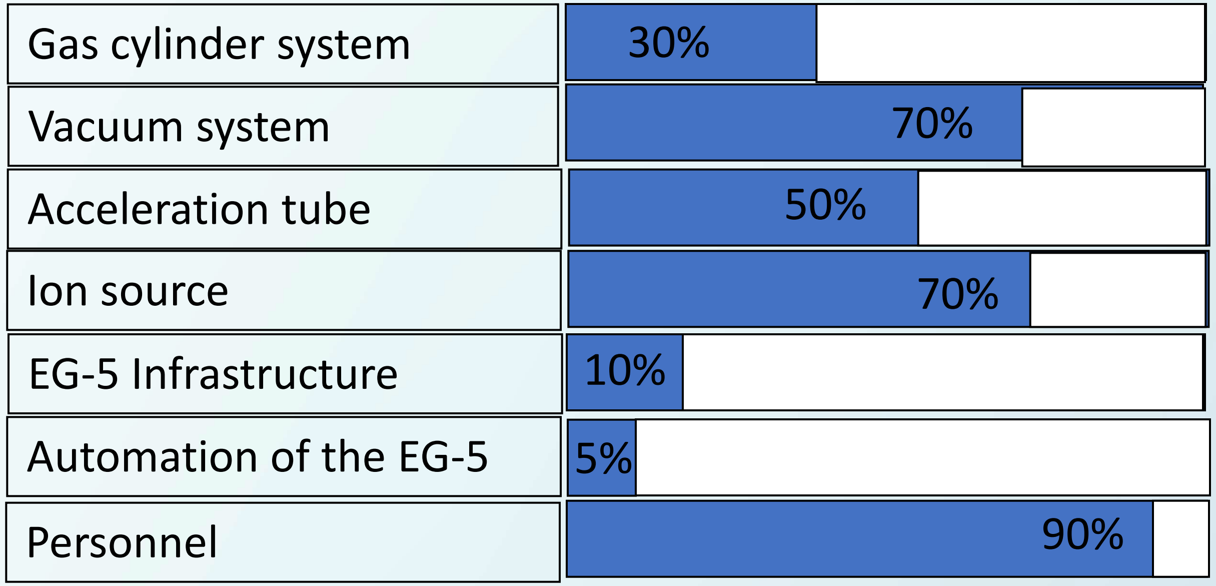
AS Doroshkevich

2013

Modernization of the EG-5

Prof. Romanov V.A. investigates ion beam profile (2021)

EG-5 Accelerator Modernization Progress



RESULTS OF 2024

The EG-5 device passport values of the ion beam current (30 μA) have been achieved.

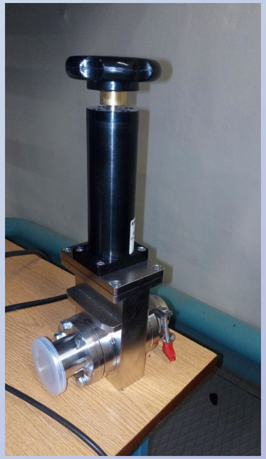
The beam energy is 85% of the technical specification value of 3.5 MeV have been achieved.

PLANS for 2024

By the end of 2024, obtain a Sanitary and epidemiological certificate (SEC) and commissioning of the accelerator

1. The gas cylinder system modernization project is at the approval stage;
2. Acceleration tube at the gluing stage;
3. Interlocking system for radiation protection of personnel at the installation stage;
4. The ion source is completely ready, a control system is required;
5. The solid target is ready for operation;
6. Documents for obtaining a certificate SEC are ready.

The limiting factor for EG-5 commissioning is the approval of the project for modernization of the gas cylinder system and installation of the radiation monitoring system.



Li- target

1. Engineering of oxide and semiconductor structures using ion beams

Introduction

Radiation technologies for processing high-energy light ions are now a universally recognized powerful "technological tool" that allows to create new types of semiconductor devices and improve the characteristics of existing ones.

Ion implantation is the only method of non–growth local doping of SiC.

It provides the formation of local doped regions, a controlled spatial distribution of impurities [[i]].

The main advantages of ion implantation as a method of creating modified surface nanolayers are:

-the ability to obtain almost any combination of materials in the surface nanolayer [[ii]],

- independence from the limits of solubility of components in the solid phase (i.e., it is possible to obtain such alloys that are impossible under normal conditions due to thermodynamic limitations),
- low temperatures of the modified material and the absence of an explicit interface,
- the absence of an adhesion problem,
- the controllability of the processing depth,
- good reproducibility and stability of the process,
- high purity of the process in vacuum,
- the ability to create complex surface nanostructures, etc. [[iii], [iv]].

[i] А. В. Афанасьев, В. А. Ильин, В. В. Лучинин Ионное легирование карбида кремния в технологии приборов силовой электроники. Обзор Известия вузов. Электроника / Proceedings of Universities. Electronics 2022 27(4) С. 439-458. doi:10.24151/1561-5405-2022-27-4-439-462

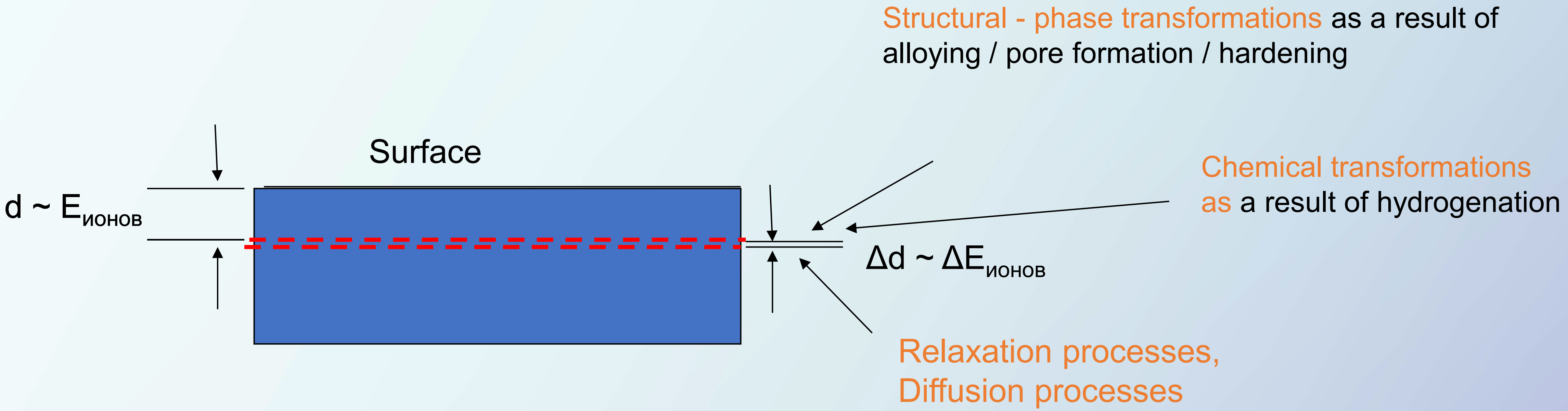
[ii] Poate J.M., Foti G., Jacobson D.C. Surface Modification and Alloying by Laser, Ion, and Electron Beams. - New York: Plenum Press, 1983. - 243 p.

[iii] Ягодкин Ю.Д. Ионно-лучевая обработка металлов и сплавов // Итоги науки и техники сер. «Металловедение и термич. обработка металлов». М.: ВИНИТИ, 1980. Т.14. С.142-185.

[iv] Хаюров С.С. Термическая и химикотермическая обработка металлов и сплавов с использованием ионных и лазерных пучков // Итоги науки и техники сер. «Металловедение и термич. обработка металлов». М.: ВИНИТИ, 1990. Т.24. С.167-221.

Unique features of the EG-5

- processes of structural relaxation of the surface layers of solids, accompanied by oxidation or hydrogenation (Metallic (Fe, Cu) and metal oxide (ZrO_2, CuO, ZnO, SnO_2) solid solutions - ceramics, etc.);
- studies of the oxygen subsystem of the surface layers of materials by the method of nuclear reactions (> 3.1 MeV, NRA).



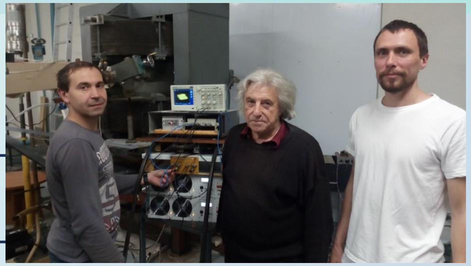
- Interaction of nuclear radiation with matter, comprehensive studies of the radiation resistance of materials for various purposes, research of materials for nuclear reactors;
- The use of ionic surface treatment of metals in order to increase their hardness, wear resistance, corrosion resistance;
- Radiobiological research.
- Neutron activation analysis

New equipment

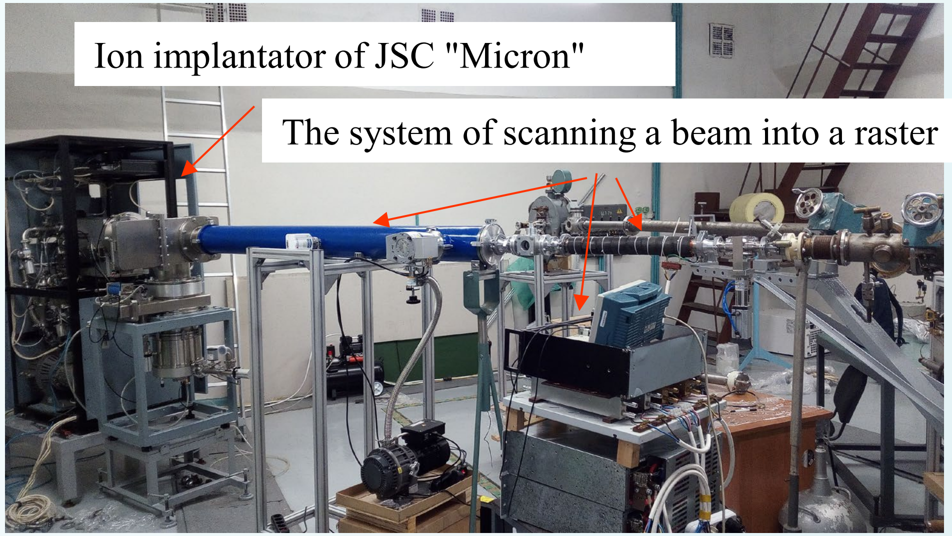
mikron ангстрем

Silicon Wafer Radiation Treatment System for Electronics

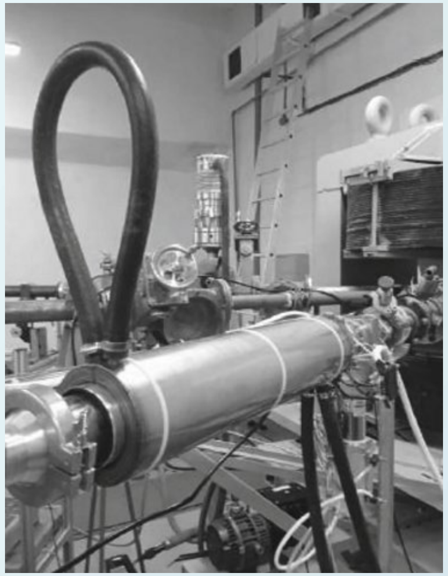
The ion implanter "DNEPR" (JSC Micron) was set up in the left experimental hall of EG-5



V.S. Rikhvitsky



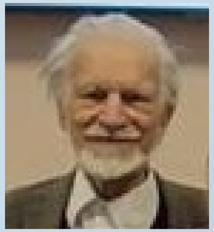
Appearance of the ion implanter "DNEPR"



Deflection system [1]

Luminescence of a quartz plate in a beam of H^+ ions

I.A.Chepurchenko



V.N. Semenov

L.M. Ledo Pereda

A system for scanning an ion beam into a raster was developed and applied by employees of the Nuclear Physics Materials Science and Ion Implantation Nanotechnology Sector [1].

Works on ion beam treatment of industrial batches of silicon wafers for high-voltage electronics is planned for early 2025.

[1] L. M. Ledo Pereda et al., Physics of Particles and Nuclei Letters, Vol. 21, No. 4, pp. 938–945 (2024)

JOINT INSTITUTE FOR NUCLEAR RESEARCH

The new method of studying the physical properties of Si-plates

FRANK LABORATORY OF NEUTRON PHYSICS

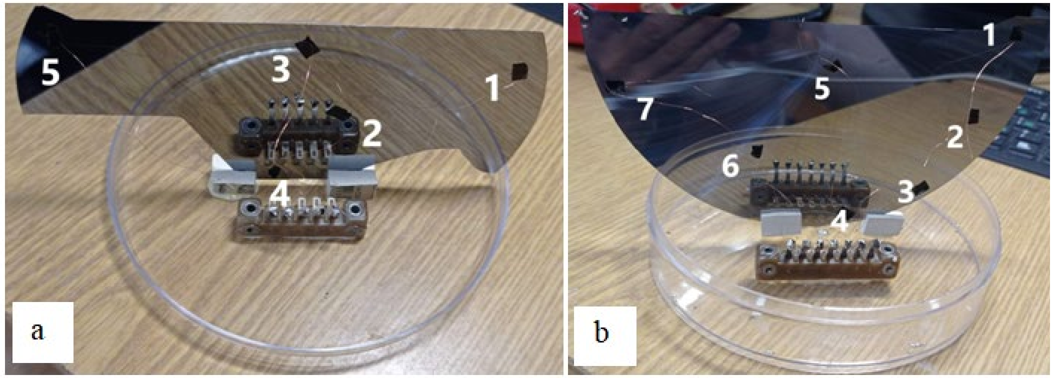


Рис. 4 Расположение электродов на контрольном (a, без облучения) и обработанном ионами диске (b). Цифры на пластинах соответствуют порядковому номеру контакта.

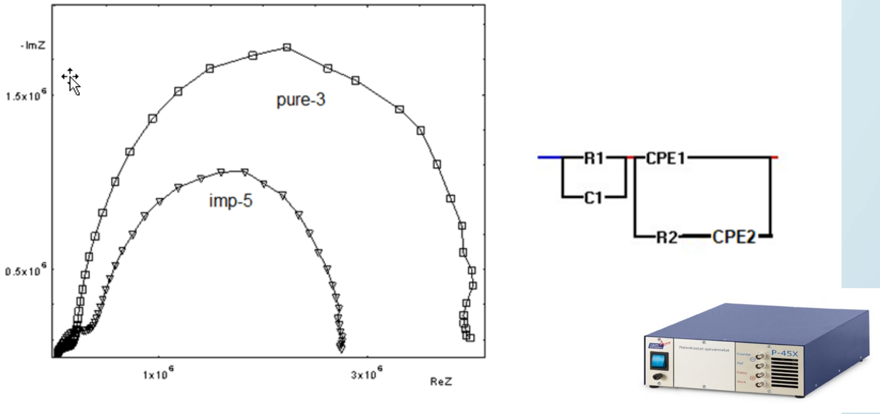


Рис. 5. Годографы для двух центральных точек пластин без (pure-3) и после ионно-лучевой обработки (imp-

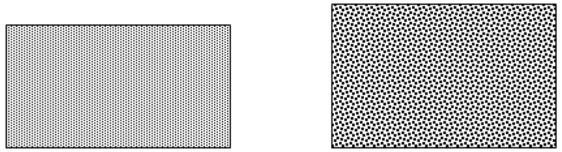


Рис. 10. Схематическое изображение объекта исследования до и после имплантации ионов легких
ов.

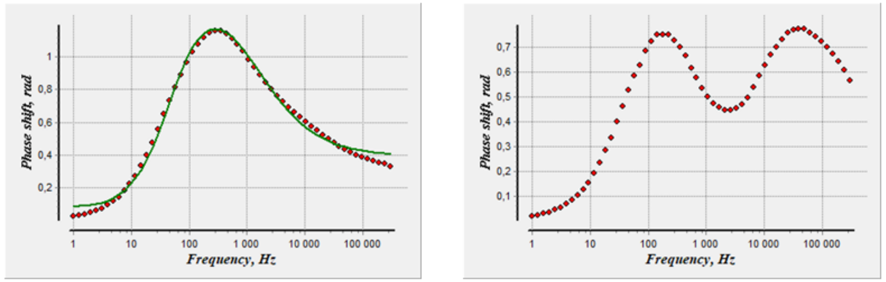


Рис. 6. Фазовая диаграмма для центральной точки контрольного образца без (a) и образца после радиационной обработки (b).

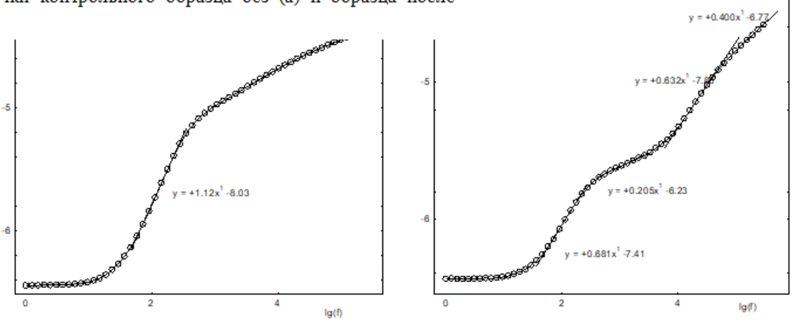


Рис. 11. Зависимость электропроводности образцов от частоты в двойных логарифмических координатах: a – контрольный образец; b - допированный образец.

Mezentseva Zh.V.

Kirillov A.K.

According to Fig. 11, current transfer channels with fractal dimension appear after processing $D_f = 2.362$ и $D_f = 2.264$, (corresponding to the surface fractal) in frequency intervals 100 – 1000Hz и 10^4 - 10^5 Hz correspondingly ($0.5<\alpha< 1.0$). Reducing the tangent of the slope angle of the graph at extremely high frequencies f > 10^5Hz means that charge transfer is carried out mainly in a thin surface layer. Presumably, after radiation treatment, the specific density of the skin layer increases due to the discontinuities of the crystal formed as a result of ion implantation. Such a morphological transformation probably leads to an improvement in the dynamic characteristics of the silicon structure at high frequencies and in pulsed modes.

Methods of IBA. Determination of the spatial localization of implanted ions

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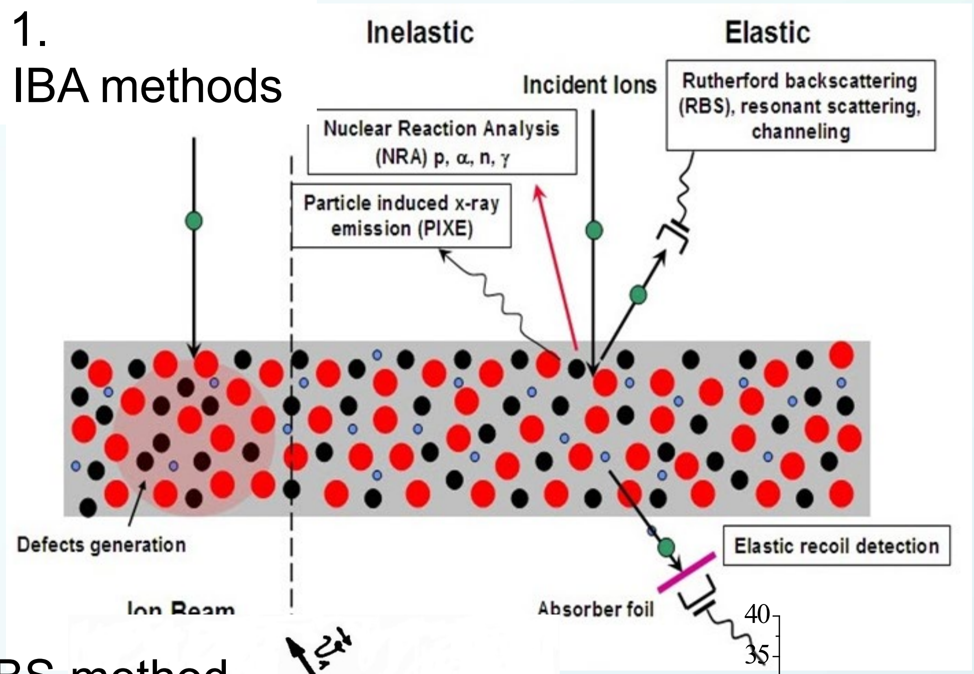
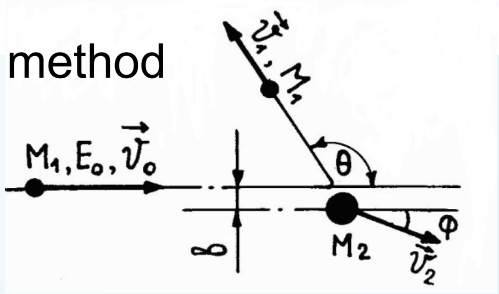
Fig. 1.
The IBA methods



The RBS method



$$\frac{M_1V_0^2}{2} = \frac{M_1V_1^2}{2} + \frac{M_2V_2^2}{2} \quad (1)$$

$$M_1V_o = M_1V_1\cos(\theta) + M_2V_2\cos(\Phi) \quad (2)$$

$$M_1V_1\sin(\theta) - M_2V_2\sin(\Phi) = 0 \quad (3)$$

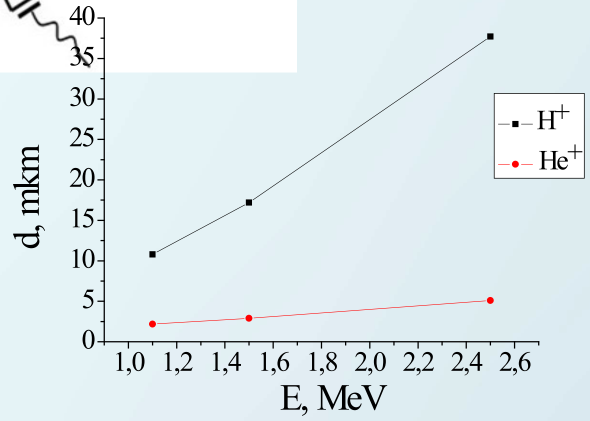
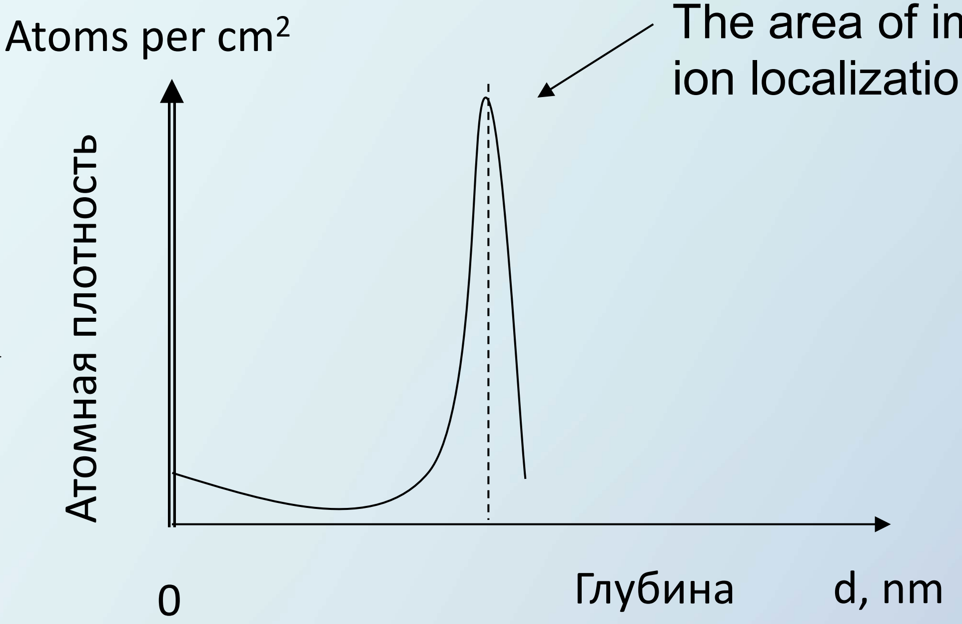


Fig.3. Ion mileage in ZrO_2



The area of implanted ion localization

Fig. 2. Schematic representation of the technique for determining the location of the implanted ion layer

IBA methods make it possible to determine the spatial localization of the implanted ion layer.

Ion beam technologies allow both the physical modification of Si materials by an ion beam and the study of the effects of radiation exposure.

The method of studying the elemental composition of Si-plates

Research on silicon multilayer architectures. Silicon substrate

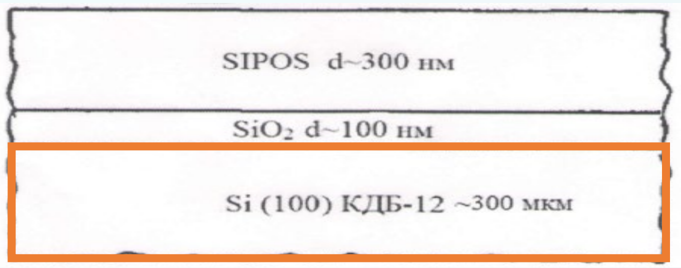


Fig. 1. Cross section of SIPOS specimens

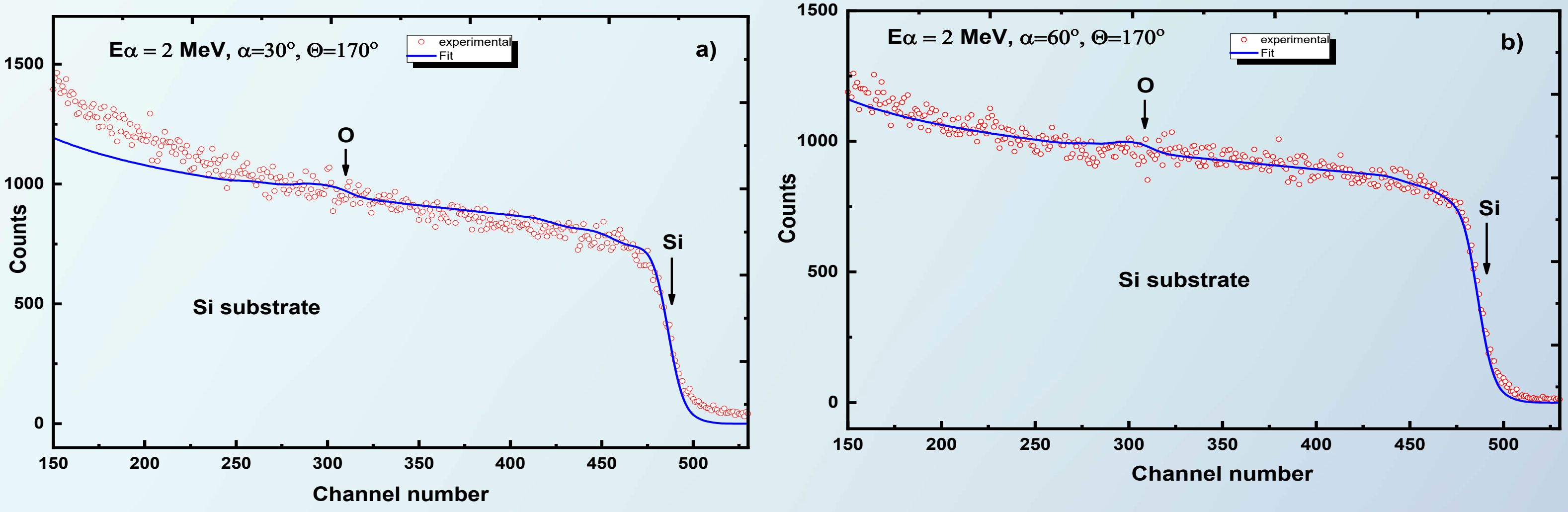


Fig.2. Experimental and theoretical spectra of RBS ions $^4He^+$ (E_0 = 2 MeV) for pure silicon KDB-Si-12 obtained at incidence angles of 30° и 60°.

Table 1. Distributions of elements over the thickness of the KDB-Si-12 silicon substrate.

layer number	Layer thickness, nm	Elemental composition averaged over the layer volume	The silicon/oxygen ratio corresponds to the composition of the layer
1	9,7 ±2 нм	$Si_{0.86}O_{0.14}$	$Si_{6,1}O$
2	9,7 ±2 нм	$Si_{0.95}O_{0.05}$	$Si_{19}O$
Substrate	∞	$Si_{1,00}$	

The thickness of the Si–O layer is 19,4 нм

Research on silicon multilayer architectures. Silicon substrate + SiO_2 Layer

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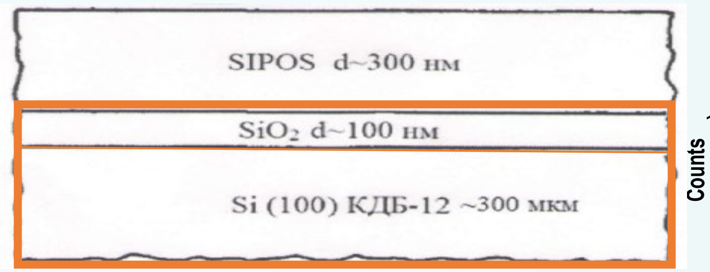


Fig. 1. Cross section of SIPOS specimens

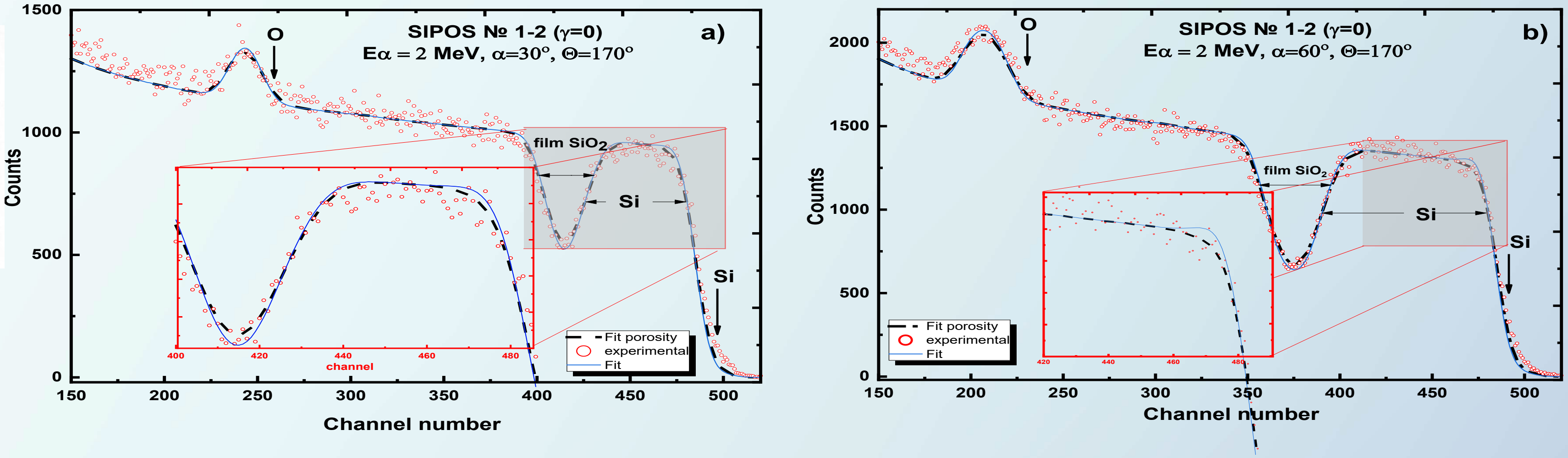


Рис. 3 Experimental and theoretical spectra of RBS ions $^4He^+$ (E_0 = 2 MeV) for KDB-Si-12 silicon with an oxide film (sublayer) obtained at angles of incidence30° и 60°.

Table 1. Distributions of elements over the thickness.

The thickness of the Si–O layer is 33,4 нм

layer number	Layer thickness, nm	Elemental composition averaged over the layer volume	The silicon/oxygen ratio corresponds to the composition of the layer
1	1 ±2 нм	$Si_{0.86}O_{0.14}$	$Si_{6,1}O$
2	5 ±2 нм	$Si_{0.95}O_{0.05}$	$Si_{19}O$
3	13,7 ±2 нм	$Si_{0.95}O_{0.05}$	$Si_{19}O$
4	13,7 ±2 нм	$Si_{0.95}O_{0.05}$	$Si_{19}O$
5	75,2 ±2 нм	$Si_{0.67}O_{0.33}$	Si_2O
Подложка	∞	$Si_{1,00}$	

The presence on the silicon substrate of a silicon oxide film of substoichiometric composition $Si_{0.67}O_{0.33}$ with a thickness of about 75 nm, which corresponds to the composition of Si_2O.

Research on silicon multilayer architectures. Silicon substrate + SiO_2 + SIPOS Layers

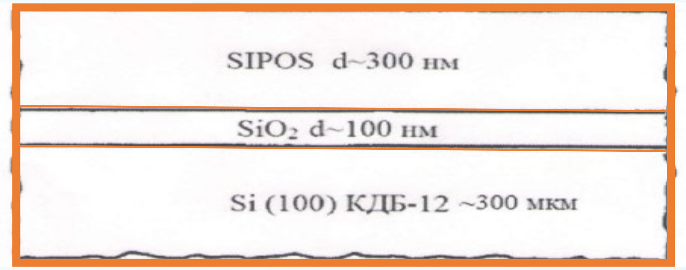


Fig. 1. Cross section of SIPOS specimens

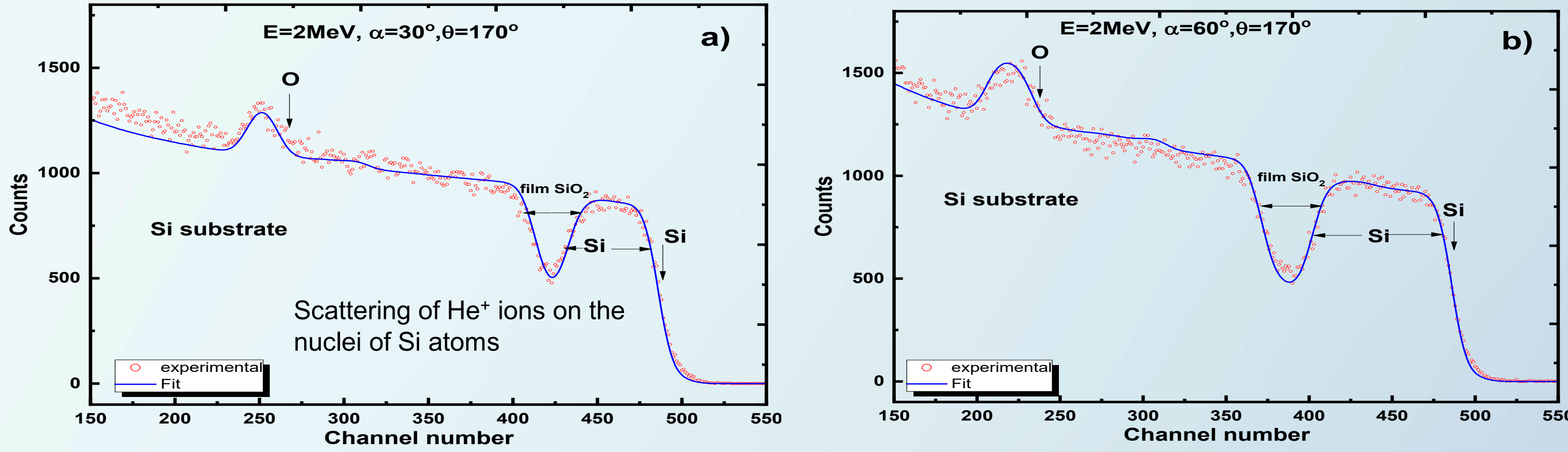


Рис. 4 RBS spectrum from a sample with a Si-O sublayer and a SIPOS layer №9 (0,1 (N_2O/SiH_4)) obtained at angles of incidence 30° и 60°.

Table 1. Distributions of elements over the thickness.

layer number	Layer thickness, nm	Elemental composition averaged over the layer volume	The silicon/oxygen ratio corresponds to the composition of the layer
1	1 ±2 нм	$Si_{0.8}O_{0.2}$	Si_4O
2	2 ±2 нм	$Si_{0.82}O_{0.18}$	$Si_{4,5}O$
3	11,7 ±2 нм	$Si_{0.92}O_{0.08}$	$Si_{11,5}O$
5	10,9 ±2 нм	$Si_{0.95}O_{0.05}$	$Si_{19}O$
4	80 ±2 нм	$Si_{0.66}O_{0.34}$	Si_2O
Подложка	∞	$Si_{1,00}$	

It is shown that with an adding the dopant N_2O/SiH_4, the silicon/oxygen ratio monotonic increases.

IBA -ILO profile assessment method

JOINT INSTITUTE FOR NUCLEAR RESEARCH

FRANK LABORATORY OF NEUTRON PHYSICS

Study of elemental composition of crystals CaF_2 and BaF_2 before and after neutron irradiation

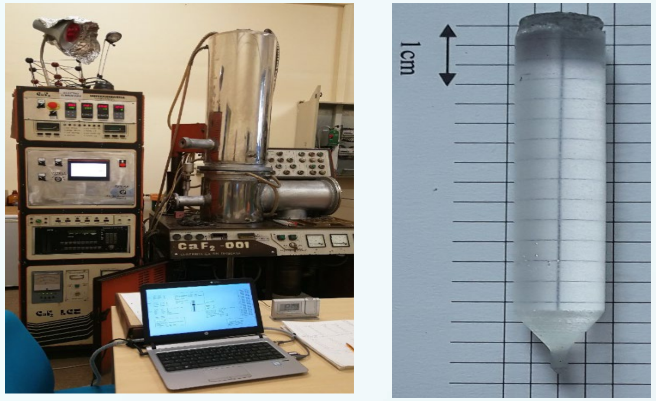


Fig. 1. Installation for obtaining and appearance of the original Fluorine crystalline drusen.
West University of Timisoara

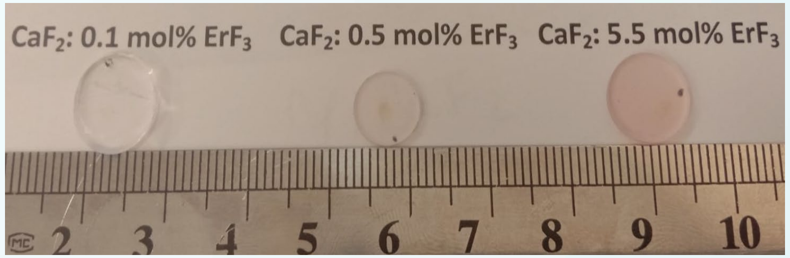
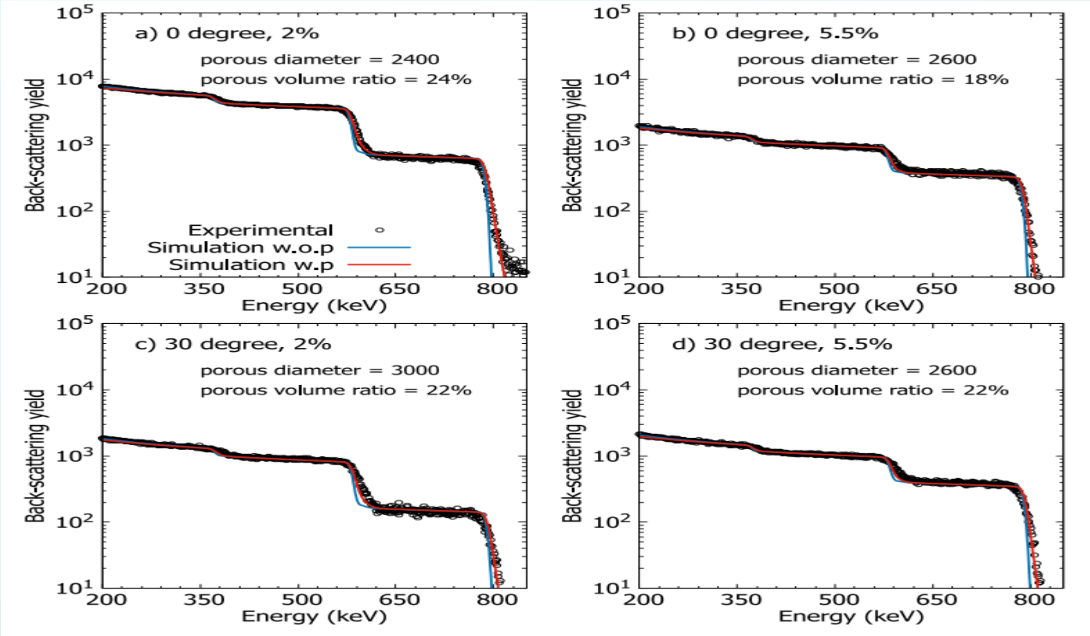


Fig. 2. Photographic shot of CaF_2 crystals with x mol% ErF_3 dopant for RBS study.

[1] Ph.L. Tuan, M. Kulik, M. Stef, T.V. Phuc. An examination on the porosity of ErF3 doped CaF2 crystal using the Rutherford back-scattering method // Nuclear Instruments and Methods in Physics Research B 547 (2024) 165178.doi.org/10.1016/j.nimb.2023.165178



In general, the obtained results provide evidence supporting the existence of pores inside ErF3 doped CaF2 crystals prepared by the Bridgman method. The likely ranges for the porosity volume ratio and pore diameter are approximately 18% to 22% and 2.4×10^{18} to 3.0×10^{18} atoms per cm2, respectively. Regrettably, the current study is hindered by a significant level of uncertainty in the methodology, impeding our ability to yield more accurate findings and draw definitive conclusions regarding the relationship between porosity characteristics and doping ratios.

Non-beam methods

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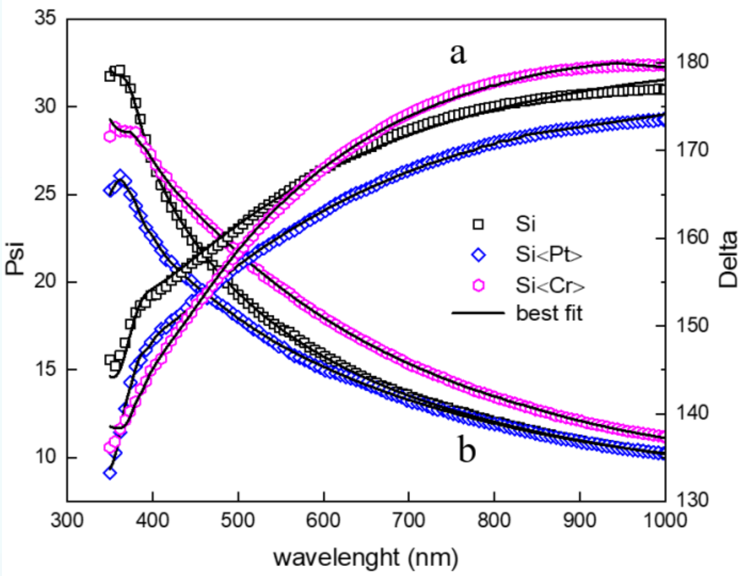
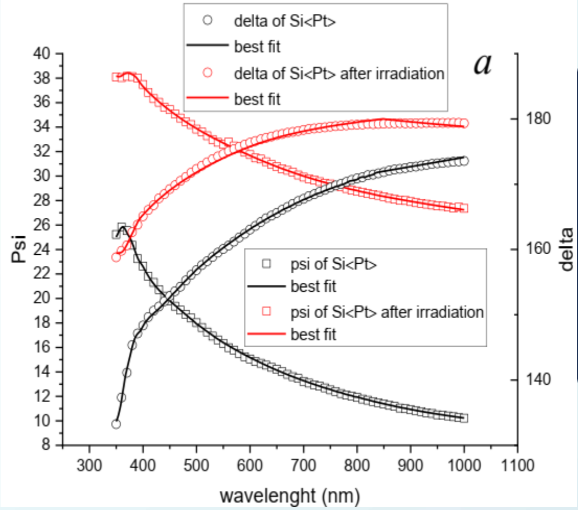
FRANK LABORATORY OF NEUTRON PHYSICS

STUDYING THE INFLUENCE OF PROTON IRRADIATION ON THE DISTRIBUTION PROFILE OF Pt AND Cr IN SURFACE LAYERS n-Si<Pt>, n-Si<Cr> USING ELLIPSOMETRIC SPECTROSCOPY (ES)

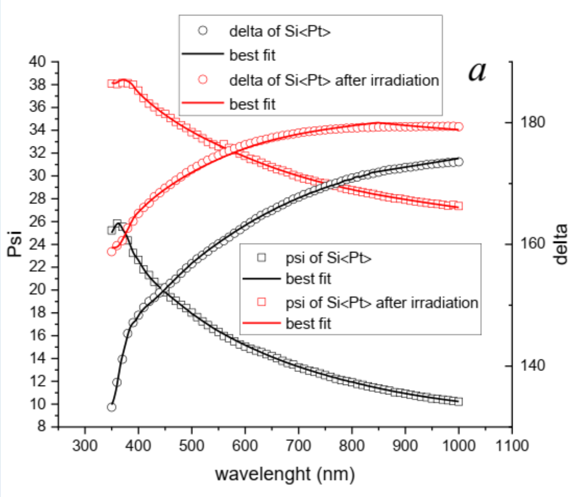
The effect of high-temperature doping and proton irradiation on the depth profile and the creation of layers on the surface of single-crystal silicon was studied. The study used single crystal n-type silicon samples doped with phosphorus during growth. These samples were first doped with platinum and chromium and after polishing they were irradiated with protons with an energy of 2 MeV, a dose of 5.1×10^{14} cm^{-2}. Studies of the optical properties of the sample surface were carried out using an ELLIPS-1991 ellipsometer.



Ψ spectra (a) and Δ spectra (b) of samples: black curve - original, blue curve - doped with platinum and pink curve - doped with chromium. The black line is the best fit curve.



Ψ spectra and Δ spectra of irradiated silicon samples: a- doped with platinum and b - doped with chromium. The black and red line is the best fit curve

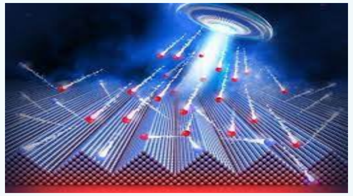


The presence of oxide layers on the surface of the original, doped and irradiated samples was established by ES. After alloying with platinum and chromium, the thickness of the surface layers in silicon doped with chromium is almost 2 times greater than in silicon samples doped with platinum. Further irradiation with protons leads to a decrease in the oxide and subsurface layers on the surface of silicon samples. We assume that this happens due to a disruption in the crystal structure of these samples.

Utamuradova, Sh.B., P. L. Tuan et al. Studying the influence of proton irradiation on the distribution profile of Pt and Cr in surface layers n-Si<Pt>, n-Si<Cr> using ellipsometric spectroscopy. Advanced Physical Research, 6(2), 83-89 (2024).

2. Ion implantation nanotechnology, powder nanotechnology

Ion Beam treatment of oxide nanoparticles



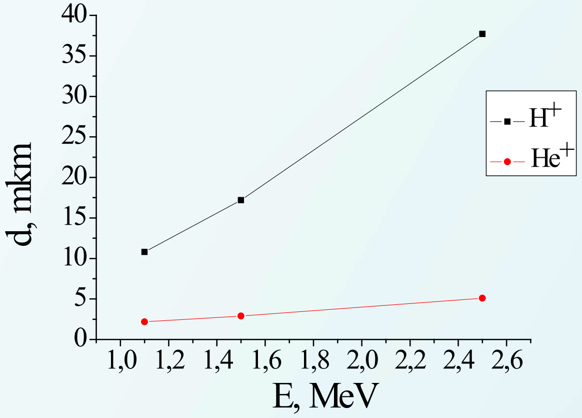


Fig.1. Ion mileage in ZrO2

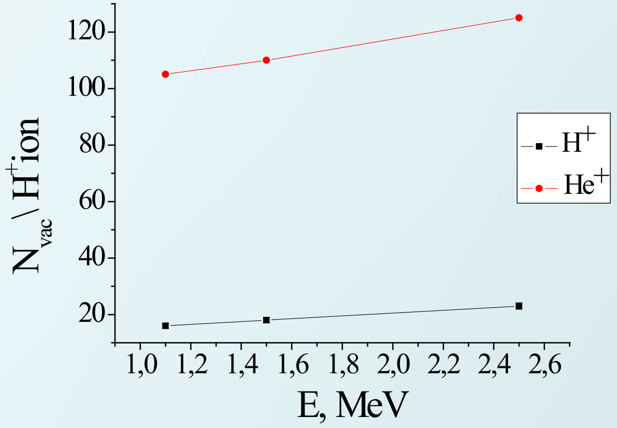


Fig.2. The number of vacancies created by injecting ion

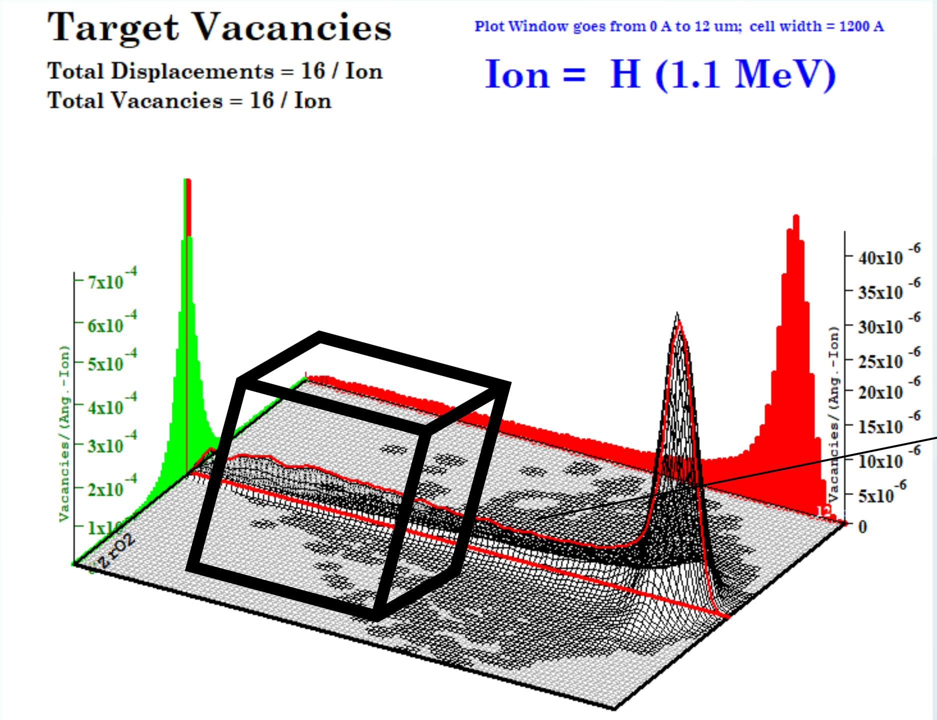
After IBT

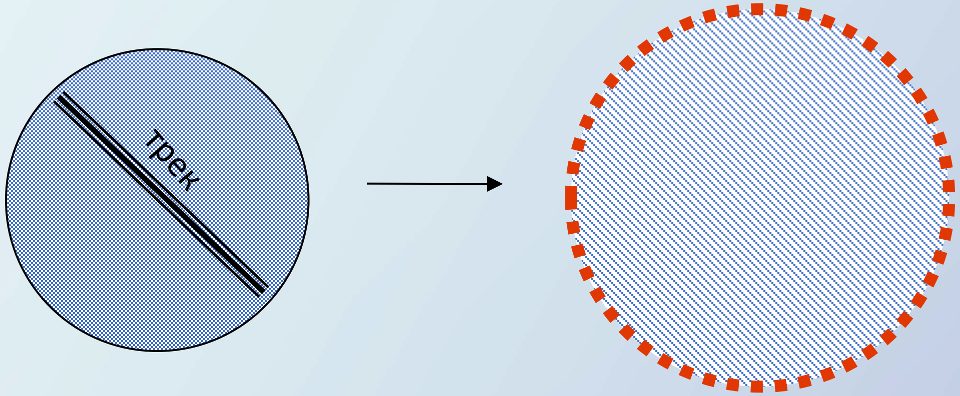
-The reactivity of the surface increases

Changes:

-The zone structure of the material

- Atomic density
- Electrical properties at high frequencies.





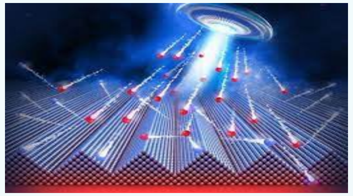
Modified by nanoparticles

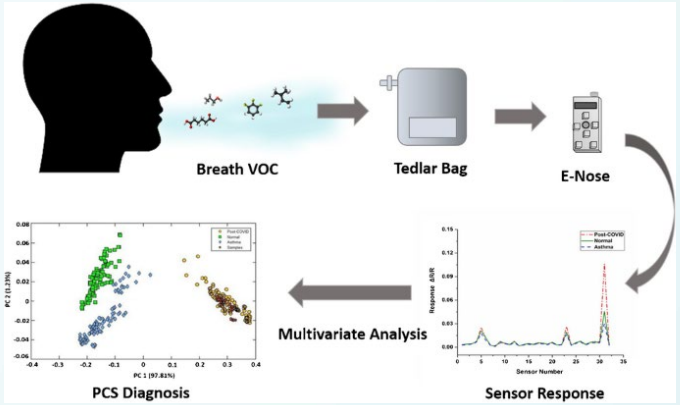
JOINT INSTITUTE FOR NUCLEAR RESEARCH

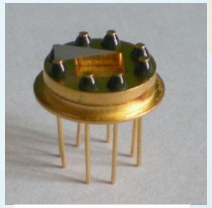
Elaboration *and research of sensors and sensor arrays*

FLNP FRANK LABORATORY OF NEUTRON PHYSICS

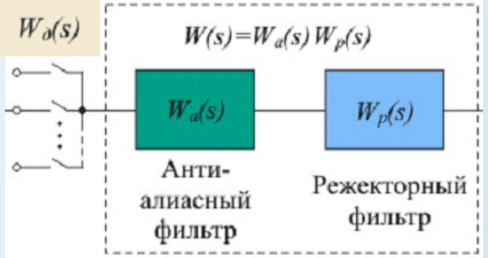
Development of the design and geometry of the E-nose elements



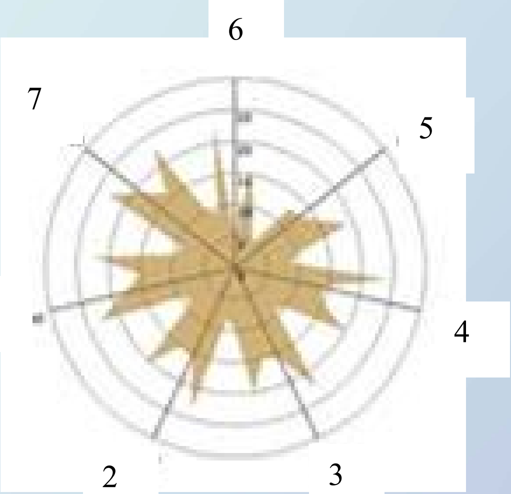




1. Sensor range



2. Signal processing module



3. Graphical image of a mixture of recognized gases

European Commission

HORIZON 2020

The EU Framework Programme for Research and Innovation

ims

UIB Universitat de les Illes Balears

THE MINISTRY OF TRANSPORT, COMMUNICATIONS AND HIGH TECHNOLOGIES OF THE REPUBLIC OF AZERBAIJAN

FCT FACULDADE DE CIÊNCIAS E TECNOLOGIA UNIVERSIDADE NOVA DE LISBOA Departamento de Química

NOVA id FCT Associação para a Inovação e Desenvolvimento da FCT

NTC Nanotechcenter

Global security system

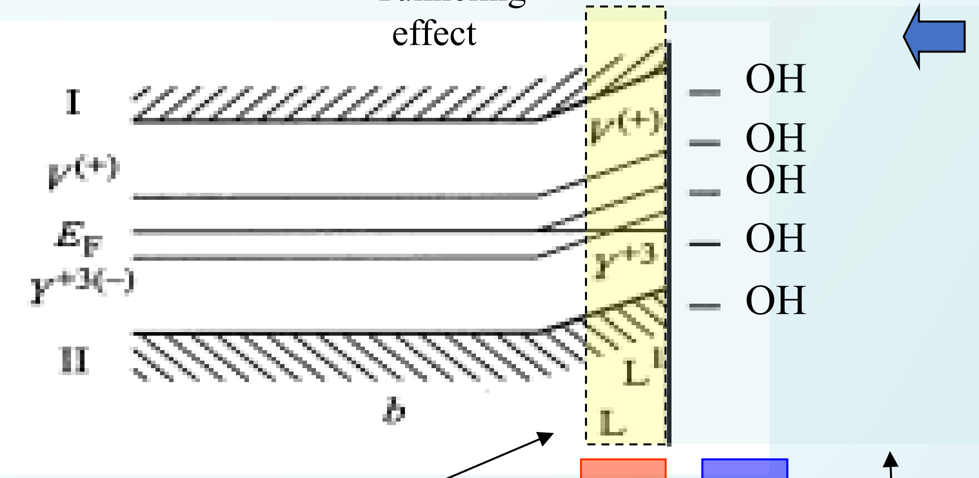
Microstructural modification at the sub-nanoscale level makes it possible to obtain materials with unique physico-chemical properties

Devices for microsystem electronic technology

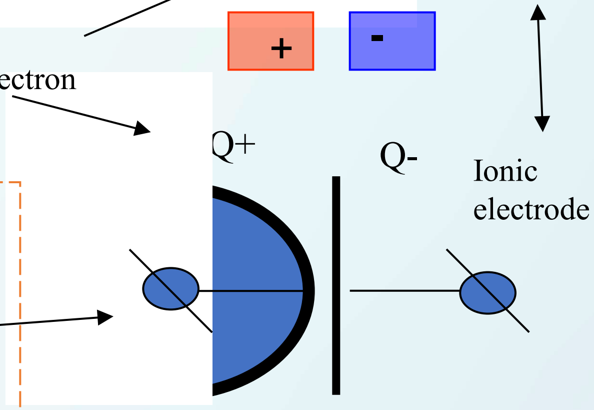
High-capacity nanoion charge storage devices

Theory

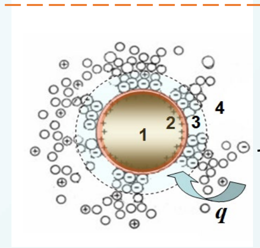
Tunneling effect



Virtual electron electrode



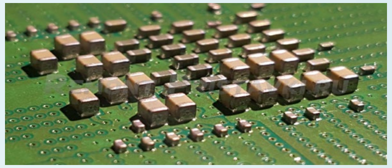
Ionic electrode



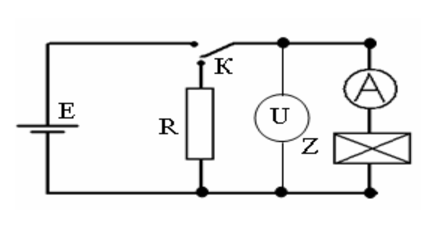
1,2 - Nanoparticle
3, 4 - Adsorption layer

$\rho_C = 10^{-3}$ F/g

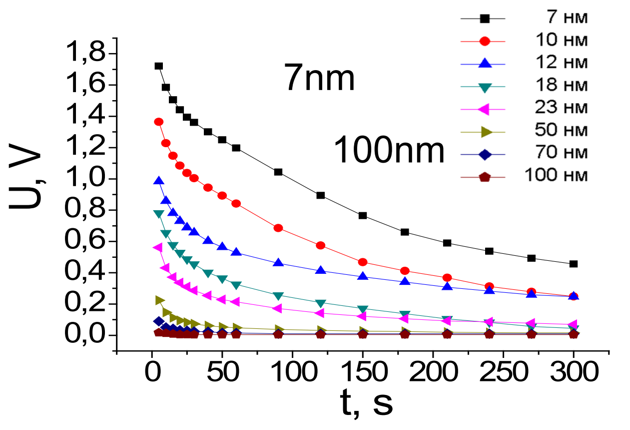
Result



Semples design
Ø=16 мм; h=1÷3мм.



Experimental circuitry
Z- sample
R - resistive load
K - switch
E - Power Supply



Discharge curves for particles of different sizes

The YSZ nanopowder system is capable of storing electricity.

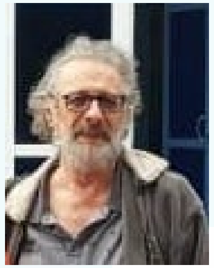
Tasks for potential projects

1) Improving the efficiency.
2) Use of polymer electrolytes.

A. Doroshkevich and el. // Nanomaterials 2022, 12, 1783. https://doi.org/10.3390/nano12111783

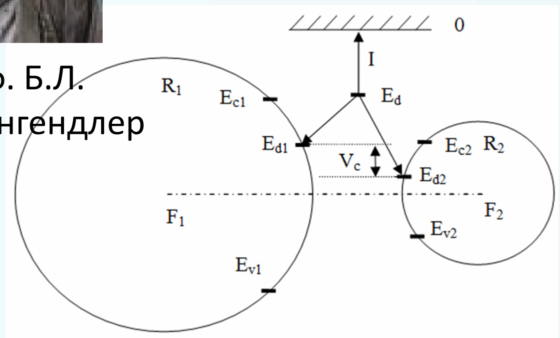
NANO Electronics based on new physical principles

The rectifying contact of hydrated different sizes YSZ - nanoparticles



Проф. Б.Л. Оксенгендлер

Theory



$$V_c = -1/2(E_{d1} - E_{d2}) \neq 0$$

$$E_d = \frac{1}{2} E_g \left[1 - 2me^4 / E_g \xi^2 \hbar^2\right]^{1/2}$$

Fig.1. The schematic interpretation of the effect of the rectifying contact, where, m and e are the mass and charge of the electron, ξ is the dielectric constant [2].

[1] B.R. Kutlimurotov, **B.L. Oksengendler** et al., Uzbek Journal of Physics, Vol. 24, No. 4, pp. 254-262, 2022. doi.org/10.52304/.v24i4.378.
[2] K.L. Keldysh, Soviet Physics JETF, 1964, 18, 1, 253

Experiment

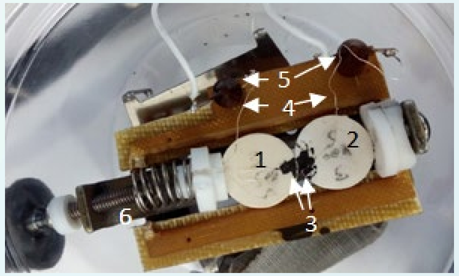


Fig.2. Experimental setup.
1, 2-compacts under study;
3-contact pads;
4-current collectors;
5-locking racks6-spring loaded clamp.

Operating Parameter \ Composition	ZrO_2	ZrO_2+3%Y_2O_3	ZrO_2+3%Y_2O_3
Maximum reverse voltage, V	>6	-0,5±0,1	>6
Maximum reverse current, μA	5±5	70±10	5±5
Maximum forward voltage, V	5±0,5	5,5±0,5	5±0,5
Maximum reverse current, μA	5±5	250±5	250±5

[6] A.S. Doroshkevich, B.L. Oksengendler et al., Nanomaterials 2022, 12, 4493. doi.org/10.3390/nano12244493.

Result

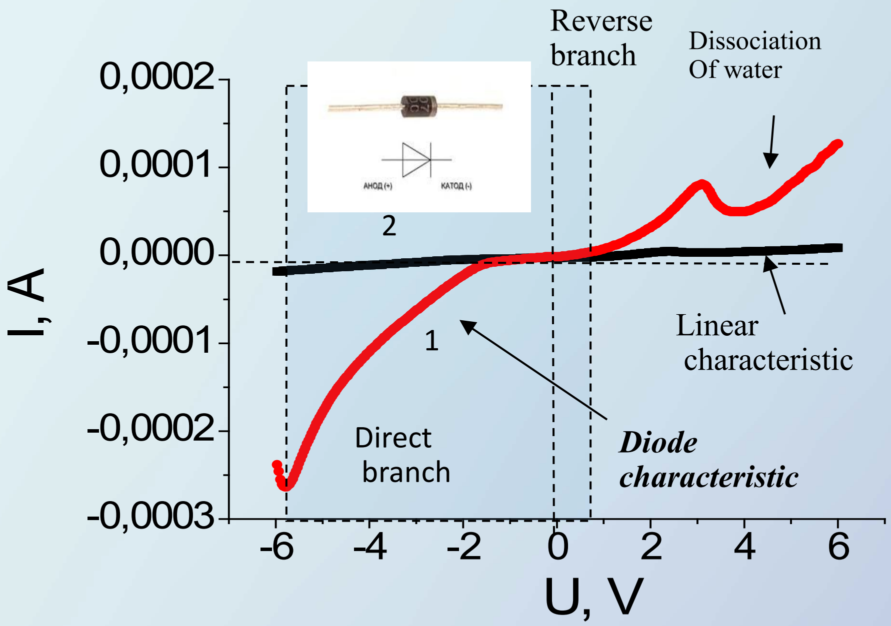


Fig.3. The contact of powders YSZ compacts. YSZ = ZrO_2 − x mol%Y_2O_3 (x = 0. 3, 8). The annealing temperatures of the powders are 400°C and 500°C. The particle sizes are 7.5 and 9 nm, respectively.

[2] K.L. Keldysh, *Soviet Physics JETF*, **1964**, 18, 1, 253

Tasks for potential projects - development of new **homogeneous electronics** devices; - Study the effects is of the superposition of the effects of 2D-3D dimensions

New energy sources

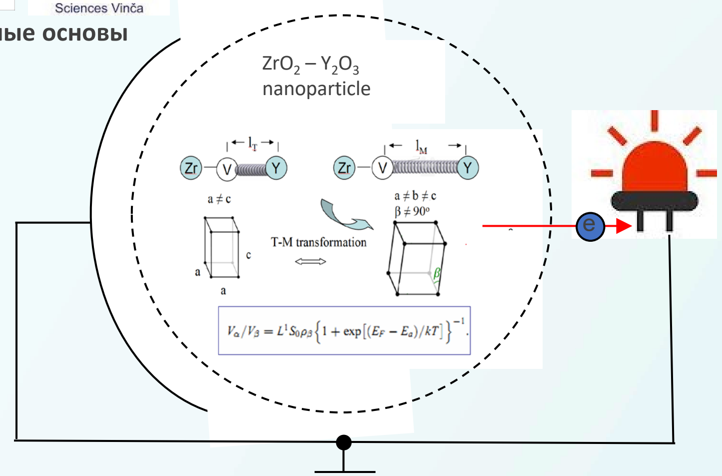
JOINT INSTITUTE FOR NUCLEAR RESEARCH

Institute of Nuclear Sciences Vinča

ims

Adsorption heat and electric generator

Научные основы

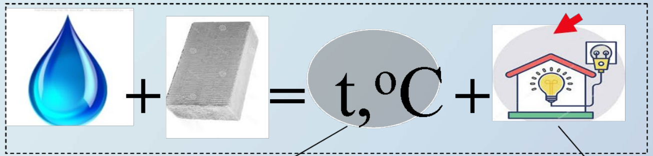


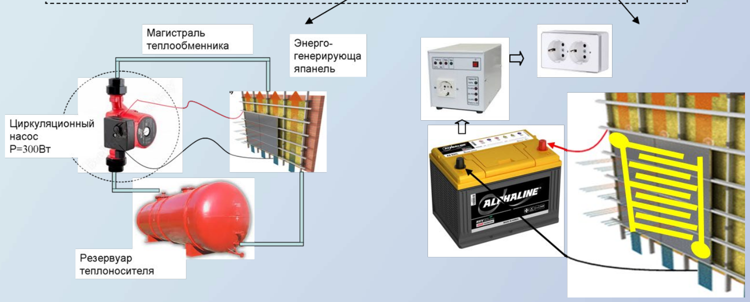
The principle of operation is adsorption–induced phase transformation in structurally metastable nanopowder systems [1].

$$ZrO_2 - Y_2O_3 + H_2O_{adsorb} \rightarrow \beta\text{-}\alpha \text{ (revers)}$$

Project objectives: Development of theoretical foundations and practical implementation on the basis of oxide nanopowders and basalt fibers of the energy-producing structure and technological infrastructure of new generation building materials. Investigation of their functional characteristics and physico-mechanical properties

Практическая реализация идеи

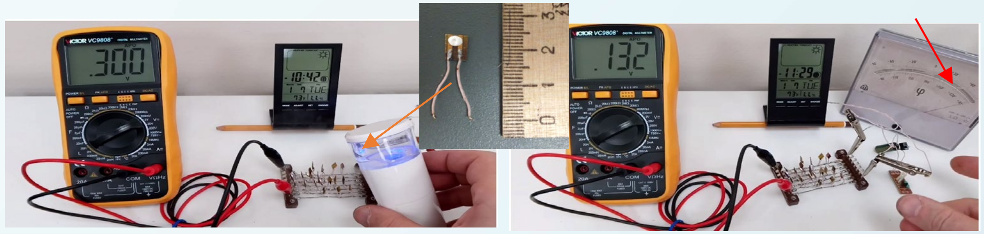




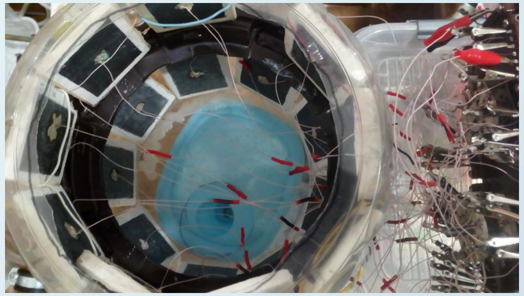
Удельная тепловая мощность :
720 kW / 1200T материала / цикл

Удельная электрическая мощность
4.32 kW / 1200T материала за цикл

Expected result: A laboratory mock-up of an energy-producing structure of the “smart brick” type with built-in technological infrastructure will be produced



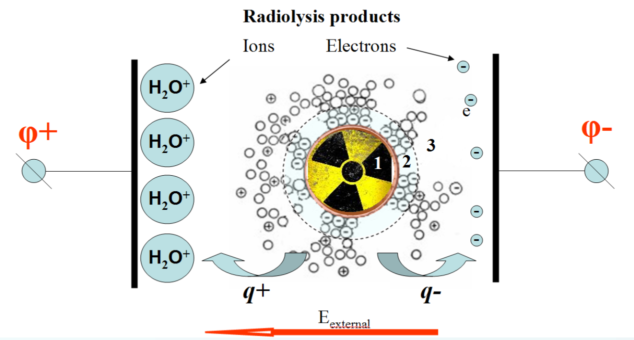
R load = 1 MOhm ; <U> = 300 mV ; <Sслоя> = 1см^2 ;W = 1 mW / m^2



R load = 100 kOhm ; <U> = 120 mV ; W = 5 mkW/kg

[1] E. B. Asgerov, A. I. Beskrovnyy, N. V. Doroshkevich, Martensitic phase transition in yttrium-stabilized ZrO2 nanopowders by adsorption of water // Nanomaterials 2022, 12, 435. doi.org/10.3390/nano12030435.
[2] A.S. Doroshkevich, B.L. Oksengendler Nanomaterials 2022, 12, 4493. https://doi.org/10.3390/nano12244493.
[3] MSCA Research and Innovation Staff Exchange (RISE) H2020-MSCA-RISE-2014. Project Acronym: HUNTER – Project Number: 691010.
[4] MSCA Research and Innovation Staff Exchange (RISE) H2020-MSCA-RISE-2019. Project Acronym: SSHARE – Project Number: 871284.
[5] A. Shilo, A. Doroshkevich et. al, PCT/UA2019/000147 (11/26/2019) “CHEMOELECTRONIC CONVERTER BASED ON ZrO_2-3mol%Y_2O_3 NANOPOWDERS”.

Radioisotope energy source



The Y-containing oxide nanoparticle is a radiation source and carrier of chemically (2) and physically (3) bound molecular water Radiolysis of water by the surface of nanoparticles will lead to the formation of free charge carriers separated by an external electric field.

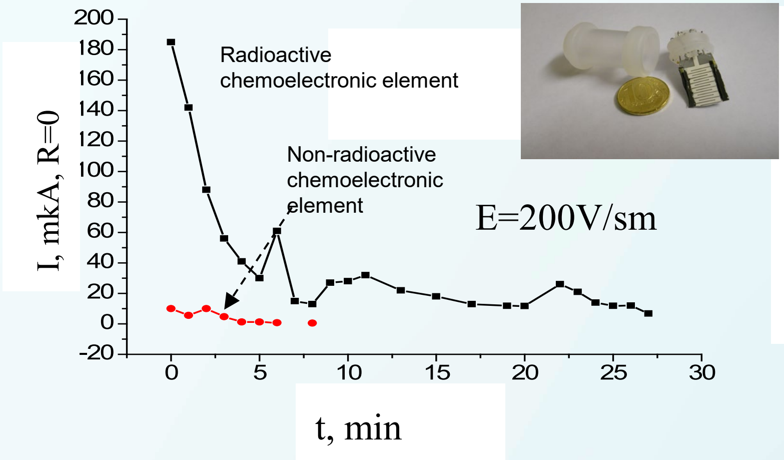


Fig. 1. Short-circuit current of the element during the working cycle.

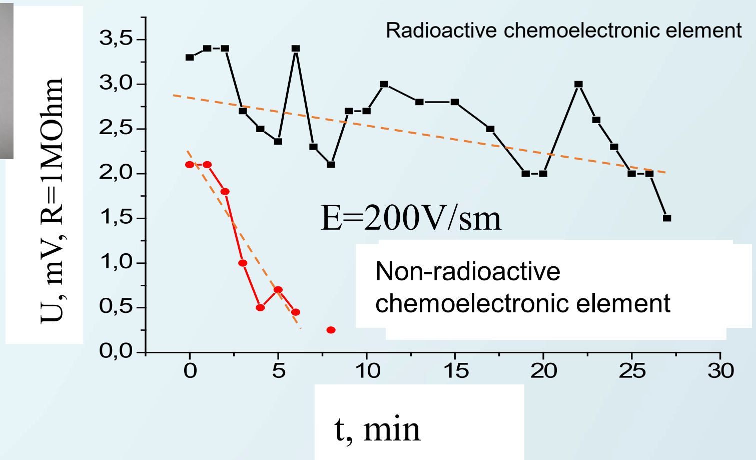


Fig. 2. The voltage of the element during the working cycle.

In the radioactive element, the short-circuit current exceeds the value in the control sample by an order of magnitude, the voltage is 1.5 times, the cycle time is 3 times.

Tasks for potential projects

1) Improving the efficiency of the converter.
2) Development of fully solid-state structures.
3) Miniaturization of the design for the needs of subvolt nanoelectronics

Methods of analysis

A multiparametric gas analysis method using impedance spectroscopy on individual sensors from the kit will be tested.

Electrochemical impedance spectroscopy

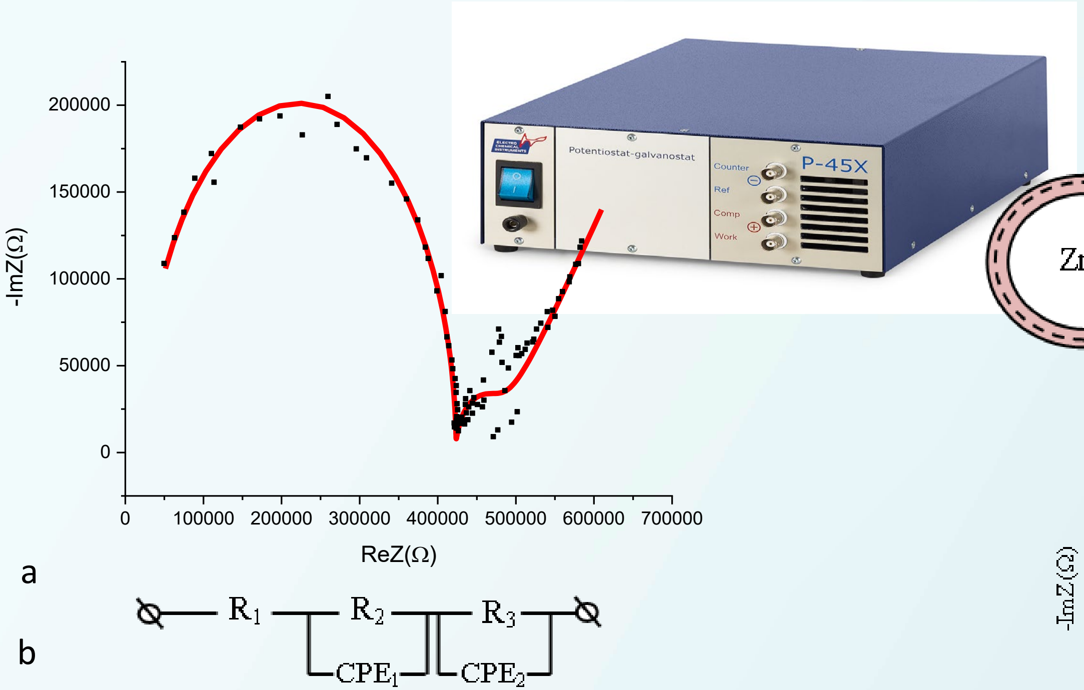


Fig. 1. Experimental hodograph spectrum of a circuit-electronic converter cell and its approximated curve using CPE (a) elements. An equivalent scheme of the approximated curve of the hodograph spectrum (b).

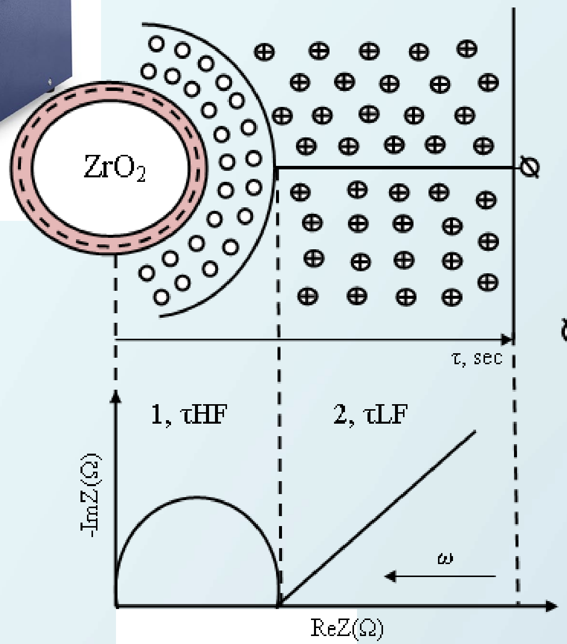


Fig. 2. Geometric representation of the functional layer of the converter system (a) and the relationship of its spatial and temporal coordinates with the shape of the hodograph (b);

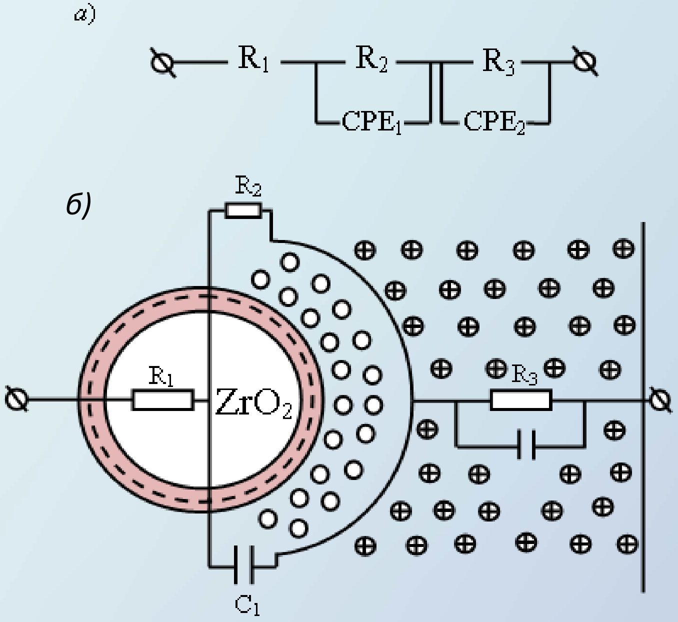
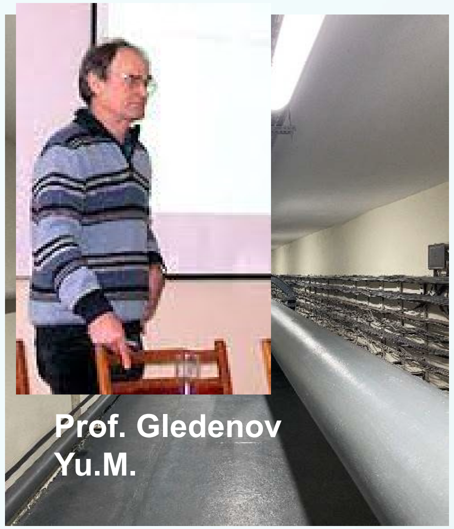


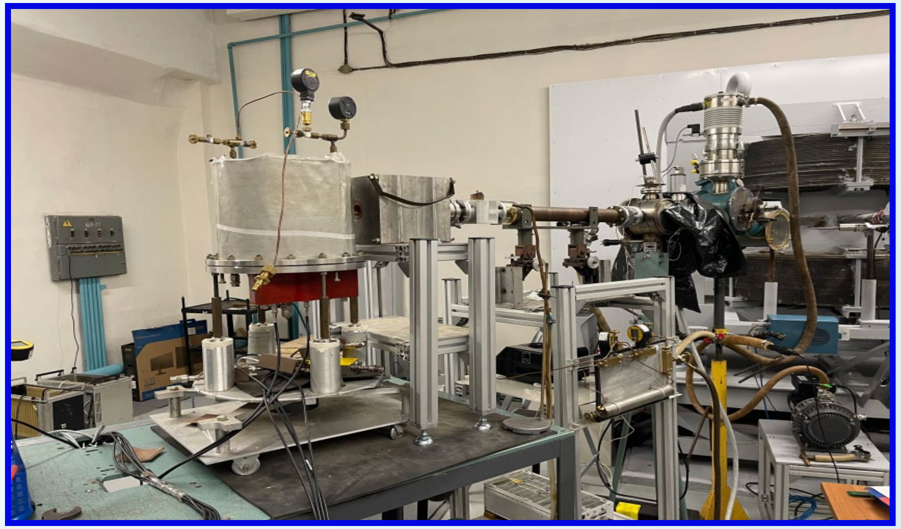
Fig. 3. Comparison of the equivalent electrical circuit of the hodographs (a) with the physical structure of the sample (b);

3. Other areas of research

Investigation of neutron-induced reactions with charge particles emission

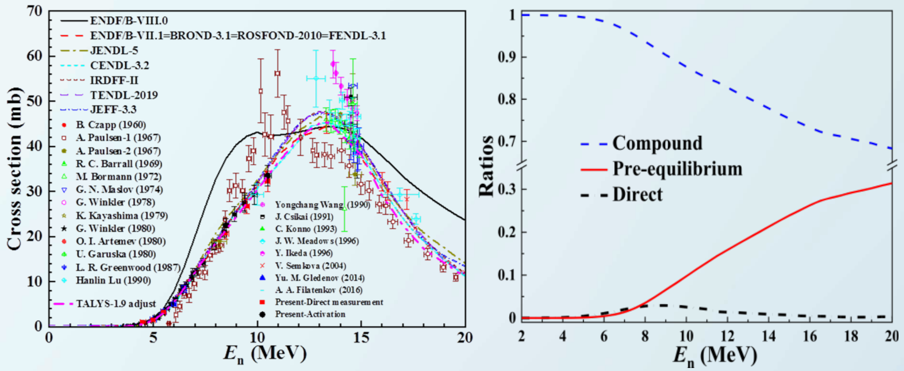


Experimental hall at IREN facility



Experimental hall EG-5, FLNP JINR

New ionization chamber for the IREN faclilty



Yu M Gledenov et.al «63Cu(n, α)60Co cross sections in the MeV region»
J. Phys. G: Nucl. Part. Phys., Vol. 50, (2023)
DOI 10.1088/13616471/acb960

Work is planned to measure cross sections for reactions (n,p), (n,α) on various isotopes.

In 2024, it is planned to measure reaction cross sections (n,α) on gas samples Ar, F, O, Ne at EG-5, FLNP JINR (En=3-5 MeV) and at the tandem accelerator HI-13 CIAE (En=8-11 MeV) using specially constructed ionization chamber.

Cross sections will also be measured for ^{148}Sm(n,α) at EG-5, FLNP JINR.

It is also planned to conduct test measurements of reactions (n,p), (n,α) on ^{6}Li and Cl at the IREN facility.
Developing a proposal for experiments at CSNS (China) is undergoing.

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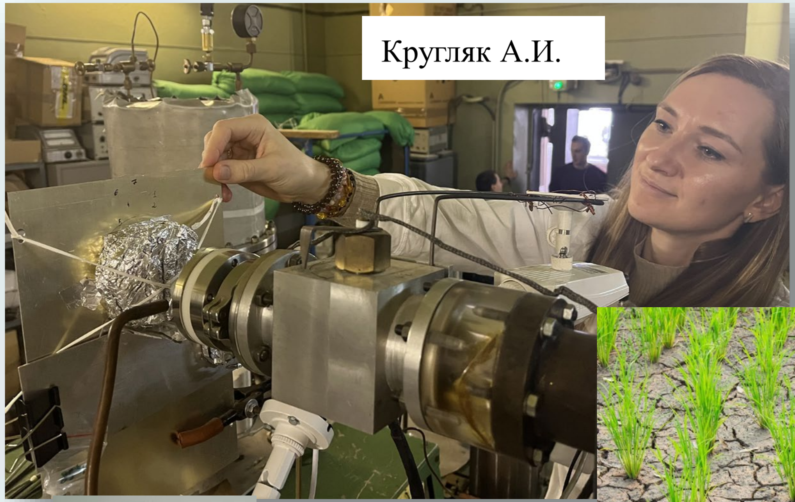
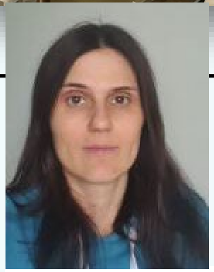
Scientific highlights EG-5

FRANK LABORATORY OF NEUTRON PHYSICS


Кругляк А.И.

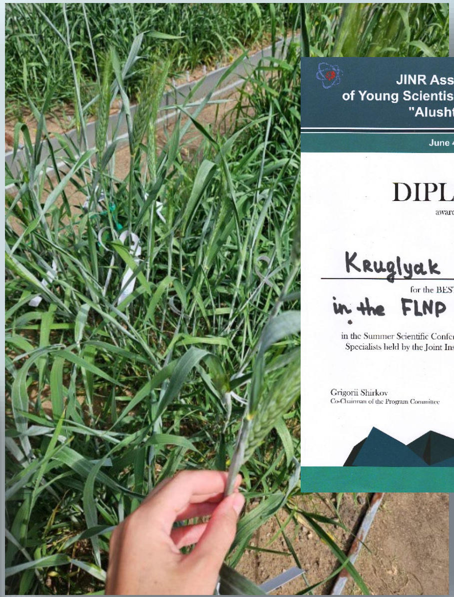

Goal →

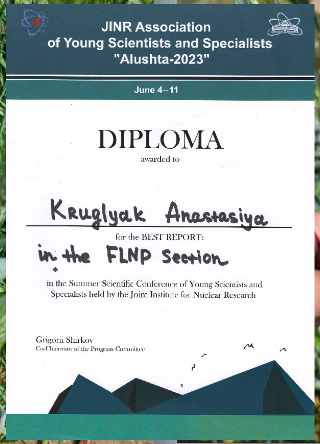

Алексеенок Ю.В.

^3He
MeV
$2\mu A$
MeV
onitor
of the PIXE-4 type
- 204 hours
- 35 - 40 million particles / hour

Obtaining economically valuable features of triticale (×*Triticosecale*) using fast neutrons mutagenesis

Drought-resistant




JINR Association
of Young Scientists and Specialists
"Alushta-2023"
June 4–11

DIPLOMA
awarded to
Kruglyak Anastasiya
for the BEST REPORT:
in the FLNP Section
in the Summer Scientific Conference of Young Scientists and Specialists held by the Joint Institute for Nuclear Research

Grigorii Shirkov
Co-Chairman of the Program Committee


Corresponding member of the Kazakh Academy of Sciences Prof. K.B. Bakiruly

Isolation every mutant M2 plant

Mutant forms **M2** (the second year of research) with desired properties are going to be used as initial forms in synthetic selection

Joint study of JINR and All-Russia Research Institute of Agricultural Biotechnology and All-Russian Plant Quarantine Center

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FRANK LABORATORY OF NEUTRON PHYSICS

Particle Beam Analysis Methods in Archaeometry and Materials Science

Institute of Nuclear Sciences Vinča

JOINT INSTITUTE FOR NUCLEAR RESEARCH

Project No: JINR-Serbia_P16 No178 from 03.03.2022, No 7

PI from JINR: Aleksandr S. Doroshkevich, Mikhail Avdeev

PI from Serbia: Roman Balvanović

Fig. 1. Samples of archaeological glasses

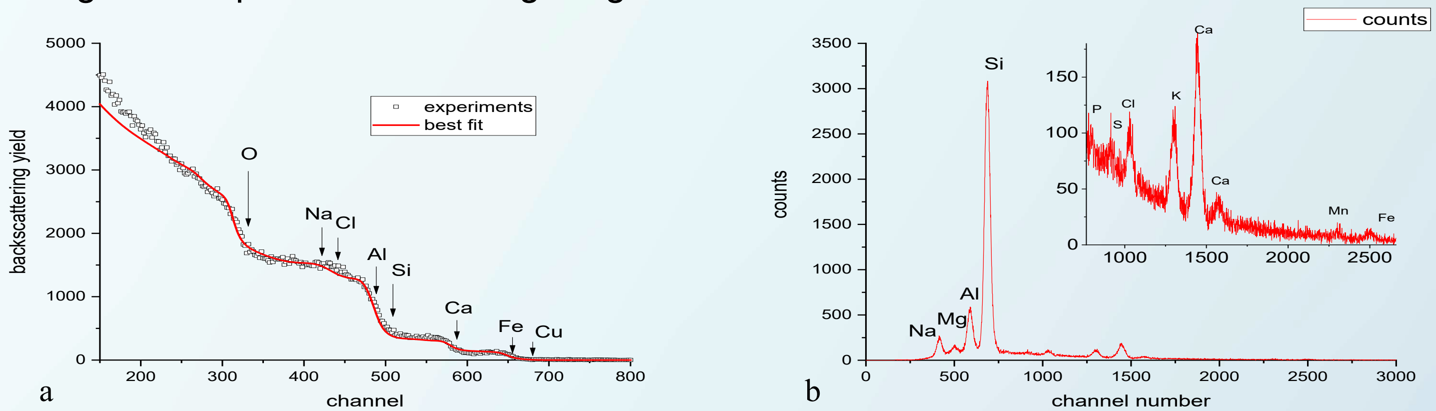

Fig. 2. RBS (a) and PIXE (b) spectra of sample C-48. Alpha particles energy: 2000 keV; Calibration sample: SiO_2/Si; Incidence Angle: 300 and 600; Scattering angle: 1700.

Relevance

Task

- Investigation of the elemental composition of archaeological glasses using nuclear physics methods.

Results

-IBA analysis of archaeological samples (glasses) was made.

- 5 abstracts of conferences and - 3 oral reports.

- 3 visits.

SOPC MODEL LIPID SYSTEMS

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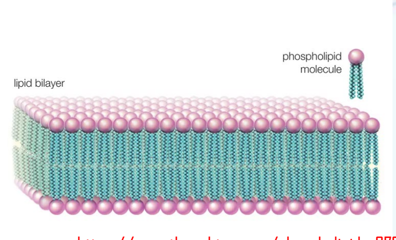
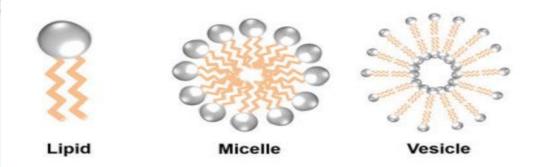
FLNP



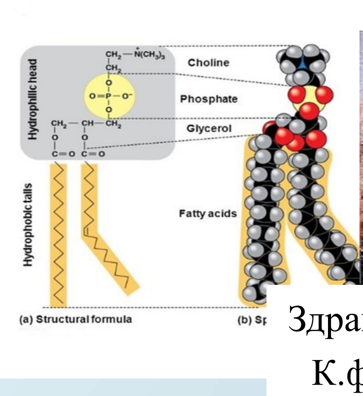
https://www.thoughtco.com/phospholipids-373561

Cell membrane backbone

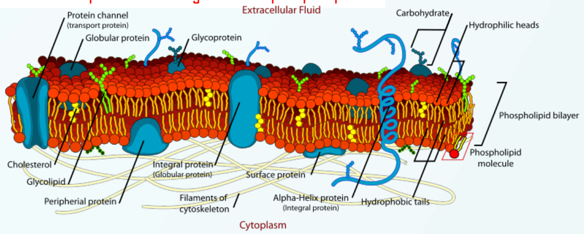


https://parksystems.com/medias/nano-academy/articles/2458-nano-pipette-based-scanning-probe-microscopy-2

Amphiphilic properties

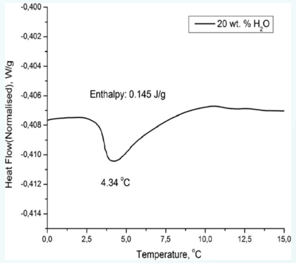


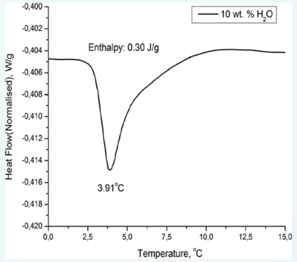
Здравка Славкова
К.ф.- м.н., с.н.с

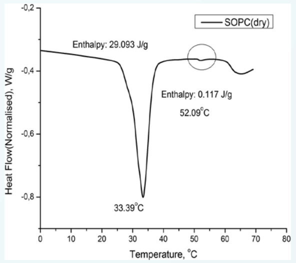


Lipids have polymorphic nature and undergo several phase transitions. Most important from a biological standpoint is the melting (main transition) gel (L_β)–liquid crystal (L_α). The L_α corresponds to the living state of cells. **Vesicles a.k.a. liposomes** consist of **bilayers** and are considered to be the cell's simplest model in terms of physics.

SOPC MULTI-BILAYERS MAIN PHASE TRANSITION AT DIFFERENT HYDRATIONS VIA DSC:



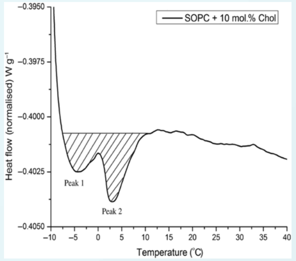


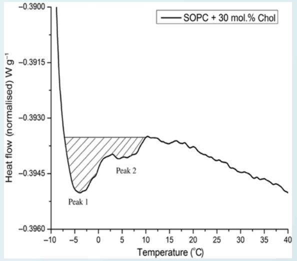


DSC analysis shows that hydration of SOPC, expressed by adding different water quantities ranging from 0 to 33 wt% dramatically influences the behaviour of thermodynamic quantities. At fixed water concentrations. Only one of both SOPC hydrophobic tail chains is involved in the H-bonding, which we identify as the sn-2 chain

	SOPC with 10w% H_2O			SOPC with 20w% H_2O		SOPC with 33w% H_2O		Dry SOPC
Heating velocity (°C/min)	0.1	2	5	2	5	2	5	5
Transition enthalpy (J/g)	0.269	0.289	0.300	0.128	0.147	0.035	0.057	29.093
Transition temperature (°C)	3.45	3.93	3.91	3.90	4.34	3.80	4.63	33.39

Generally, Chol when mixed with SOPC slightly shifts the gel (L_β)–liquid crystal (L_α) phase transition temperature, decreases cooperativity, expressed by the van't Hoff enthalpy, markedly and progressively reduces the transition enthalpy to a very low value at 50 mol.%. Concentrations below 30 mol.%, and especially those in the range 10–20 mol.%, were revealed as the optimal concentrations with regard to effective miscibility of SOPC and Chol components. The effective miscibility mainly fulfills in the gel and liquid crystal phases.





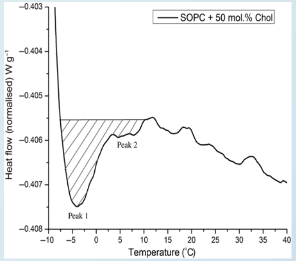


Table 1 Transition temperature and the associated enthalpy at different concentrations of cholesterol in the system

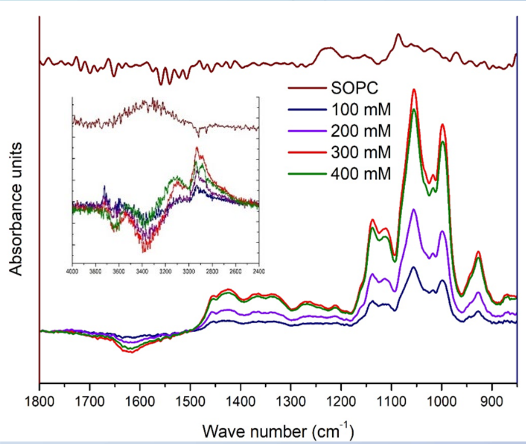
	Pure SOPC	SOPC with 10 mol.% Chol		SOPC with 30 mol.% Chol	SOPC with 50 mol.% Chol
Transition enthalpy ($J\ g^{-1}$)	0.145	0.015		0.013	0.020
Transition temperature (°C)	4.34	−3.94	3.06	−3.97	−4.01

SOPC Multi-bilayers and cholesterol main phase transition via DSC

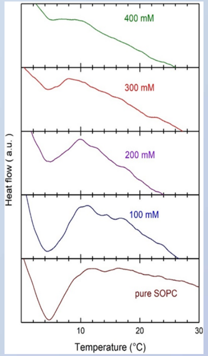
SOPC Multi-bilayers in sucrose water solution

FTIR spectra

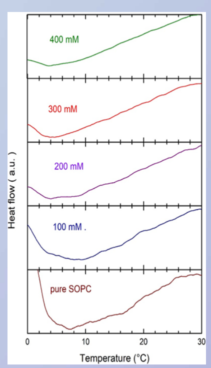
H bond to the P=O (hydrophilic head)



DSC



Heating



Cooling

Lipid topics

In the present study, both, DSC measurements and ATR-FTIR revealed a substantial influence of the disaccharide sucrose on the phase behaviour and structural properties of SOPC model lipid system.

Perovskite solar cells (PSC) with p-i-n structure

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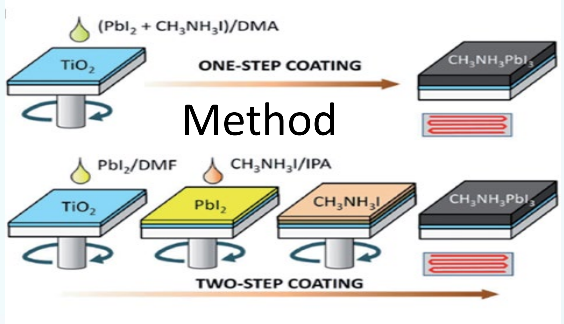
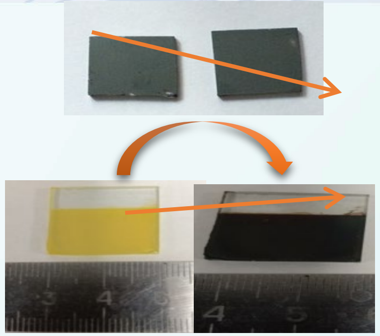
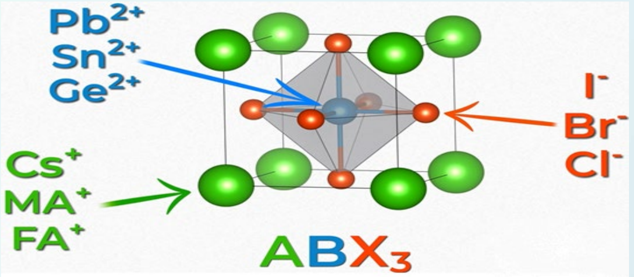


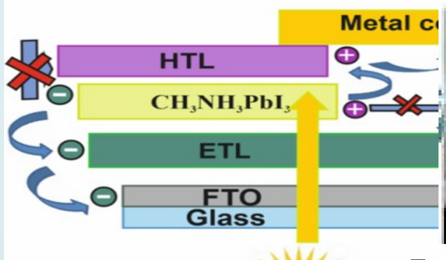


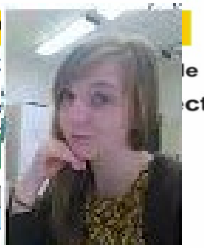
Crystal structure of the perovskite type:

MA^+ - ($CH_3NH_3^+$), FA^+ ($NH_3CH{=}NH_2^+$),



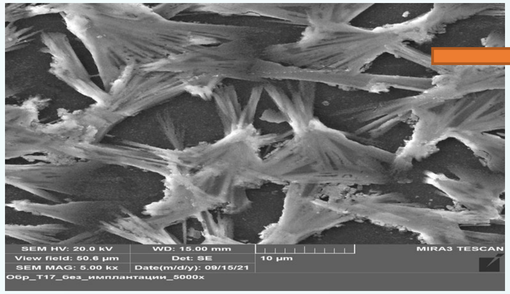
Architecture of the Perovskite solar cell

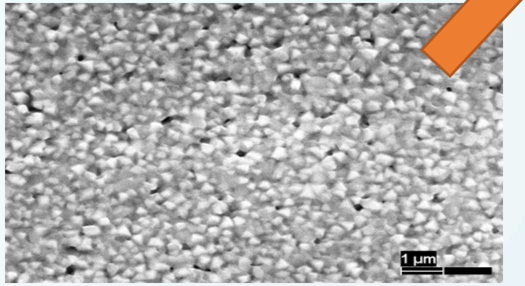


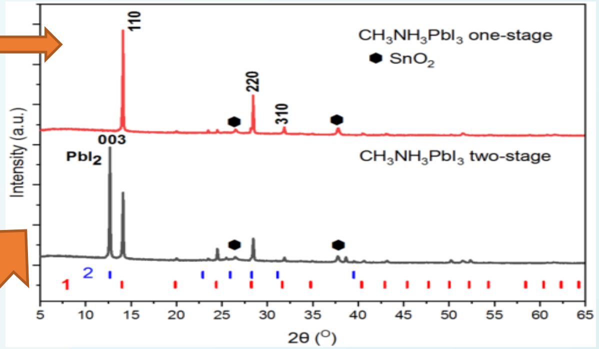


Zelenyak T.Yu.

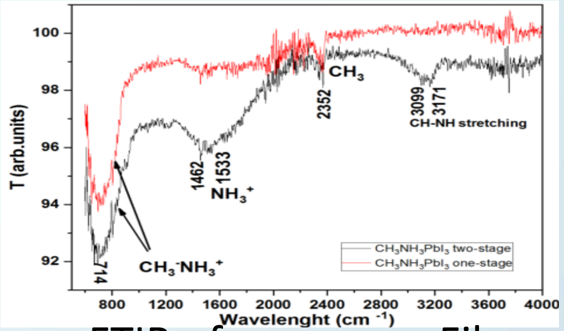
Film Properties $CH_3NH_3PbI_3$



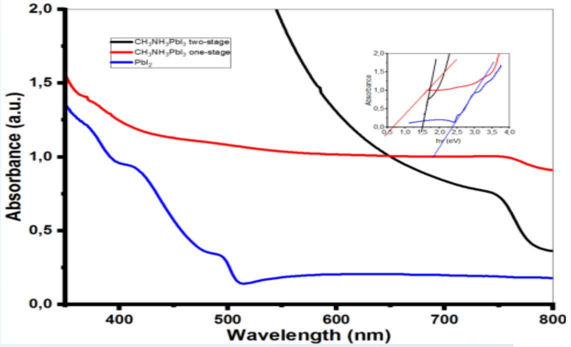




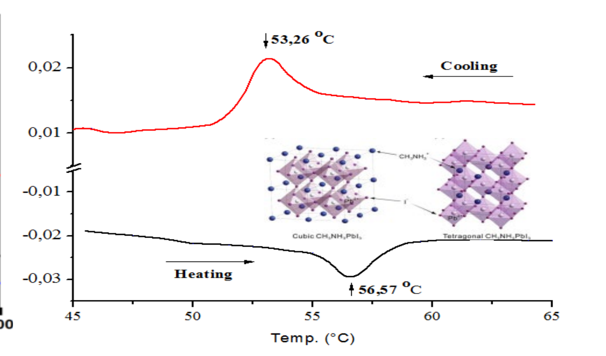
XRD of $CH_3NH_3PbI_3$ - Film



FTIR of $CH_3NH_3PbI_3$ - Film

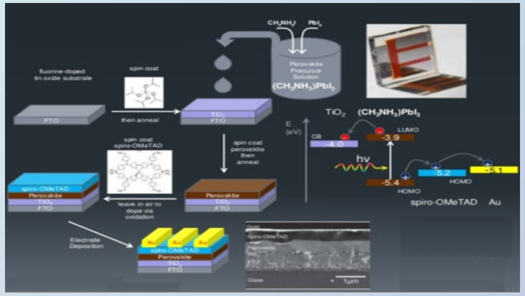


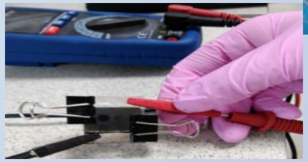
UV of the $CH_3NH_3PbI_3$ - Film



DSC of $CH_3NH_3PbI_3$ - Film

Assembly of the PSC





Future plans

Prospective projects using Ion Beam Treatment

Разработка научных основ и технологии производства «умного кирпича» на основе базальтового материала с функцией тепло- и электрогенерации

Цель проекта:

Получение новых материалов, способных обеспечивать захват и преобразование энергии внешнего термостата в тепло и электричество для перспективных строительных технологий

Ожидаемые результаты

- **Будут разработаны научные основы функционирования адсорбционных тепло- и гидроэлектрических преобразователей энергии трансформационного типа (АТГЭП) на основе наночастиц оксидов и базальтовых материалов**
- **Будут разработаны теоретические модели явлений переноса тепловой энергии, заряда и массы в неквантовых низкоразмерных системах на основе наночастиц ионных кристаллов**
- **Теоретические основы специальной функционализации наноматериалов с использованием Большой солнечной печи**
- **Будут изготовлены опытные образцы функциональных сред для исследования функциональных характеристик, электрических и теплофизических свойств, проведение физико-механических испытаний**
- **Будет изготовлен лабораторный макет энергопроизводящей структуры АТГЭП “умный кирпич” со встроенной технологической инфраструктурой (для отвода тепловой и электрической энергии)**

Задачи проекта

- **Теоретическая разработка и практическая реализация энергопроизводящей структуры и технологической инфраструктуры стройматериалов нового поколения на основе оксидных нанопорошков и базальтовых материалов**
- **Исследование их функциональных характеристик и физико-механических свойств**

Сырьевая база

Природные ресурсы Узбекистана

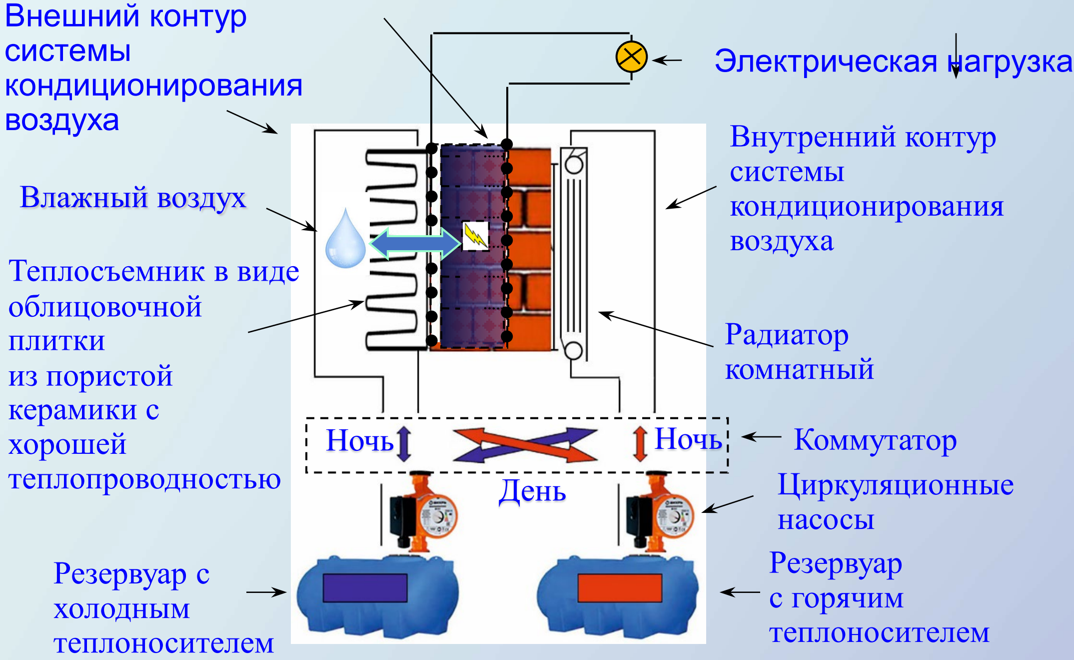
Бентонитовые глины

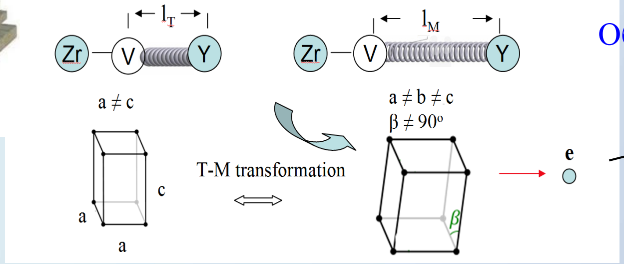
Базальтовые материалы

Отрасль применения

Заводы Узбекистана, производящие силикатный кирпич, базальтовые материалы

Конструкция и принцип действия системы





Обратимое Т-М фазовое превращение

$$n = n_0 \left\{ 1 + \exp\left[\frac{E_f - E_a}{kT} \right] \right\}^{-1}$$

[1] Alekseenko V.I. et al., // ZhTF, 2000, V70, 9, p. 57.

[2] Doroshkevich A. et. al. Nanomaterials 2022, 12, 4493. doi.org/10.3390/nano12244493

[3] Shylo A., et.al., PCT - patent WO 2021/10/107909 A1.

[4] H2020-MSCA-RISE-2014. Project Acronym: HUNTER – Project Number: 691010

[5] H2020-MSCA-RISE-2019. Project Acronym: SSHARE – Project Number: 871284

Electronic nose

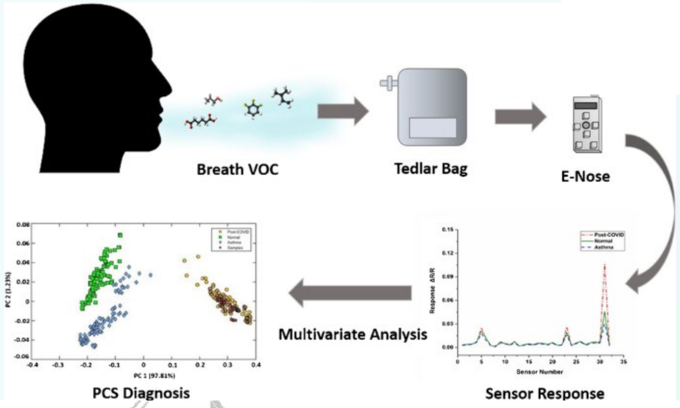
E-NOSE

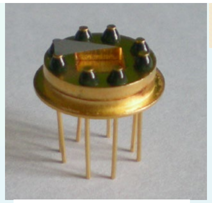
Insert logo of your entity

E-NOSE

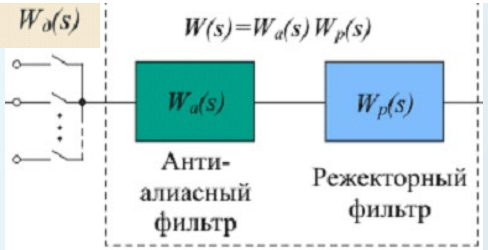
Electron Nose: Acquisition and Modification of Hierarchically Nanostructured Oxide Active Materials for Advanced Biological Gas Sensor Project

Partner presentation

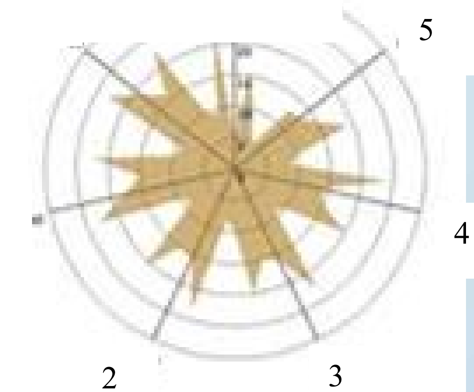




1. Линейка сенсоров



2. Модуль обработки сигналов



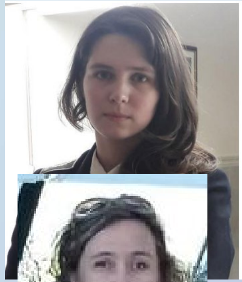
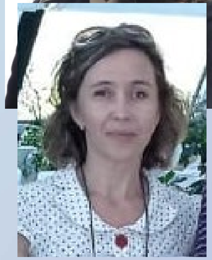
3. Графический образ смеси распознаваемых газов

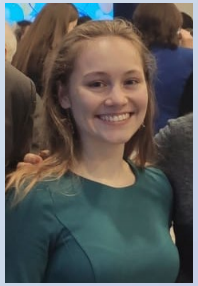
European Commission

HORIZON 2020

The EU Framework Programme for Research and Innovation

Глобальная система безопасности


UIB Universitat de les Illes Balears

FCT FACULDADE DE CIÊNCIAS E TECNOLOGIA UNIVERSIDADE NOVA DE LISBOA Departamento de Química

NOVA id FCT Associação para a Inovação e Desenvolvimento da FCT

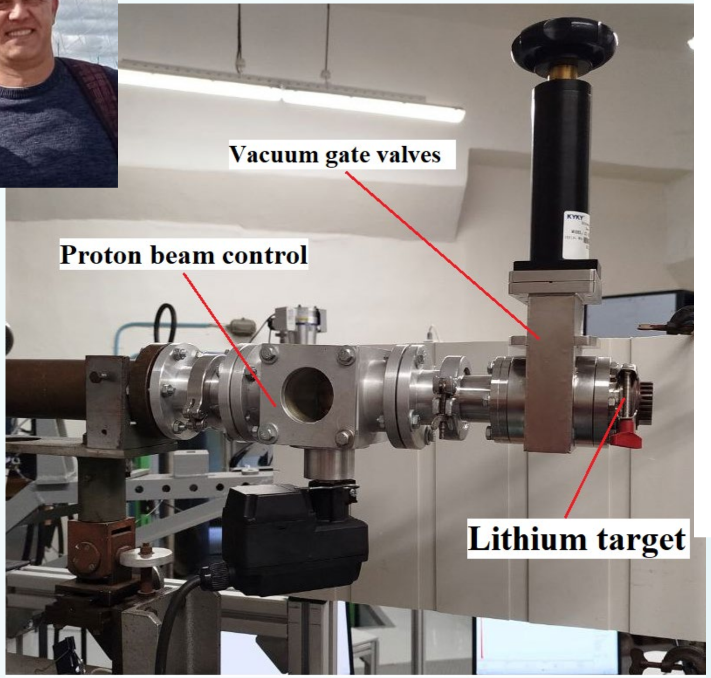
UNIVERSITAS STUDIORUM NEOPLANTENSIS MCMLX

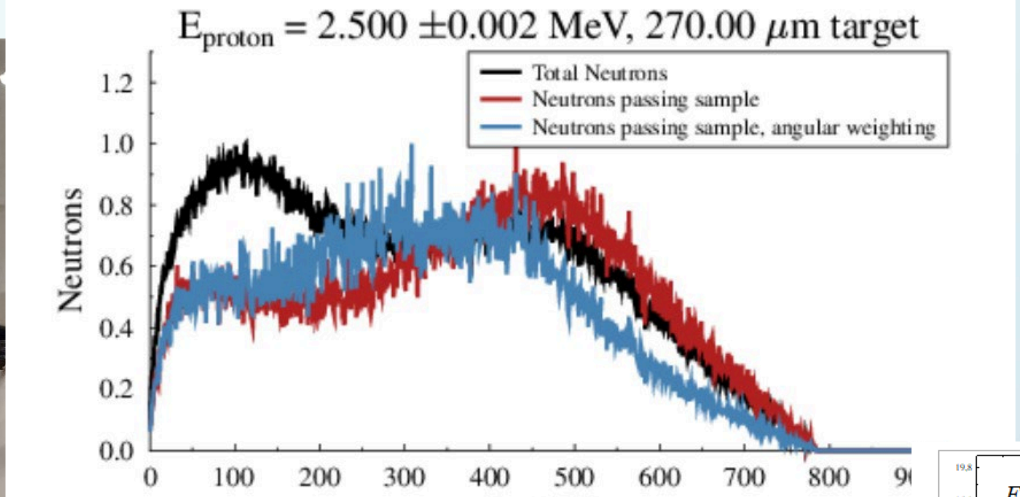
THE MINISTRY OF TRANSPORT, COMMUNICATIONS AND HIGH TECHNOLOGIES OF THE REPUBLIC OF AZERBAIJAN

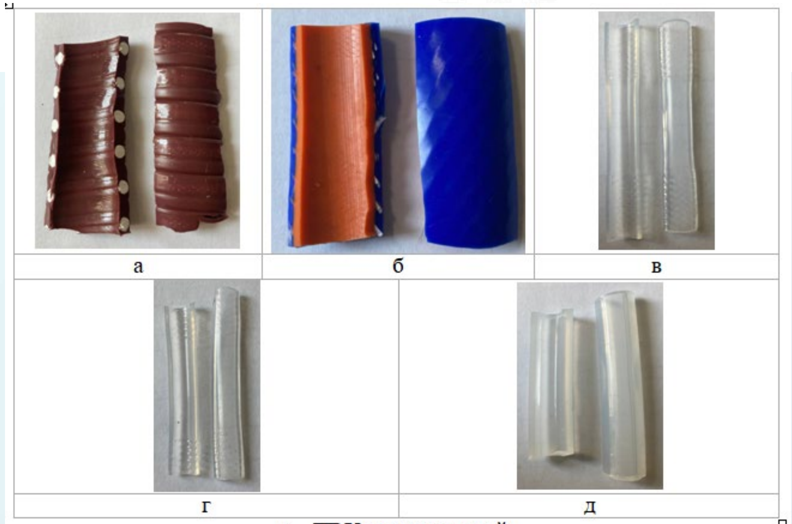
Nanotechcenter

ims

Works within the framework of the NIKA project







а – ПВХ армированный;
б – армированный силикон;

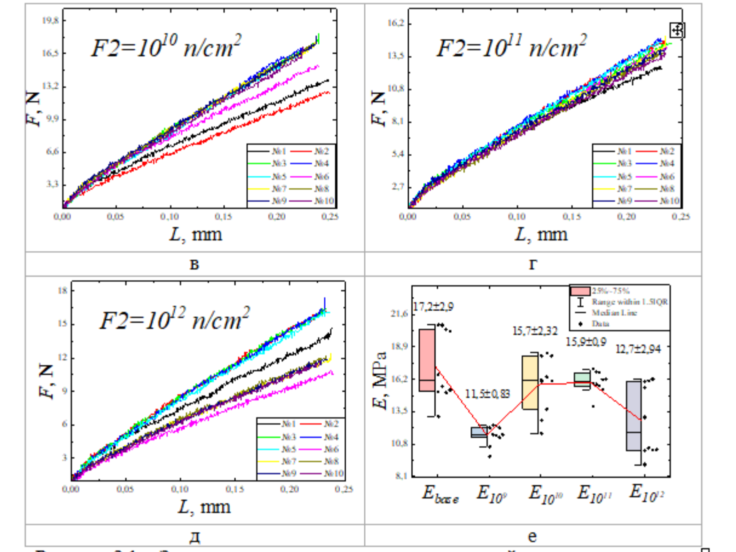


Рисунок 2.1 – Зависимости удлинения от механической нагрузки исходного и облученных образцов с разной дозой (а-д) и Chart Box по всем образцам (е)

-Investigation of the radiation resistance of polymer tubes for the detector cooling system;
-resistance of electronic components to neutron radiation.

The project with JSC Micron

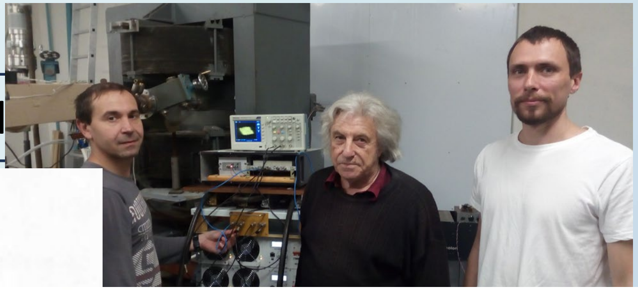
JOINT INSTITUTE FOR NUCLEAR RESEARCH

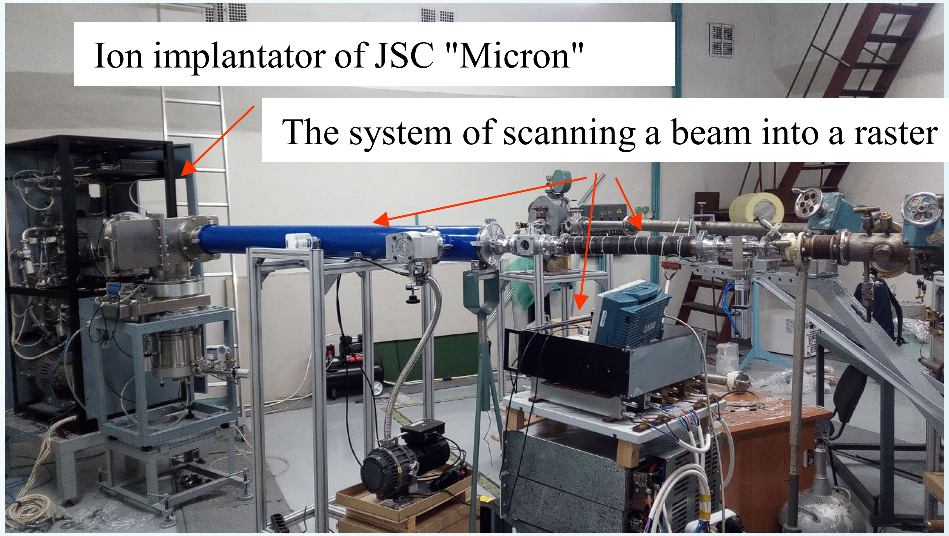
FRANK LABORATORY OF NEUTRON PHYSICS

mikron

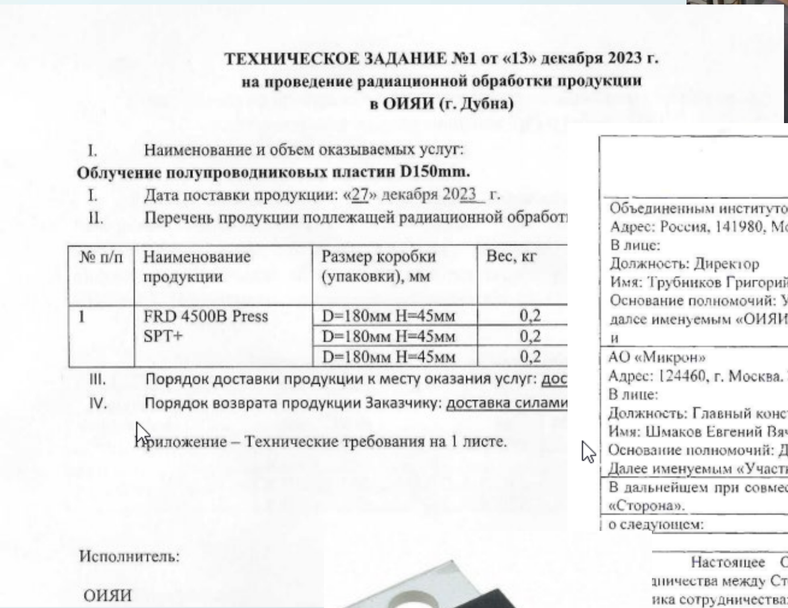
Radiation treatment of silicon wafers for electronics

The ion implanter "DNEPR" (JSC Micron) was set up in the left experimental





Appearance of the ion implanter "DNEPR"



ТЕХНИЧЕСКОЕ ЗАДАНИЕ №1 от «13» декабря 2023 г.
на проведение радиационной обработки продукции
в ОИЯИ (г. Дубна)

I. Наименование и объем оказываемых услуг:
Облучение полупроводниковых пластин D150mm.
I. Дата поставки продукции: «27» декабря 2023 г.
II. Перечень продукции подлежащей радиационной обработ

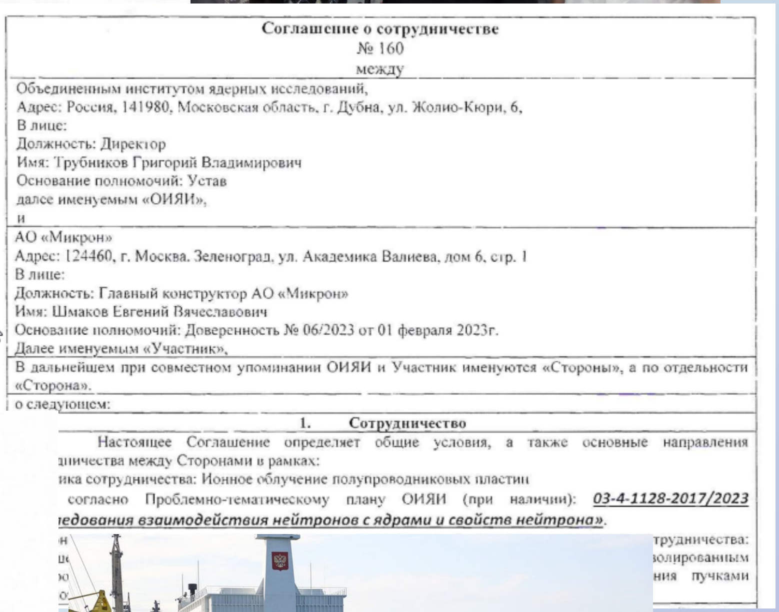
№ п/п	Наименование продукции	Размер коробки (упаковки), мм	Вес, кг
1	FRD 4500B Press SPT+	D=180мм H=45мм	0,2
		D=180мм H=45мм	0,2
		D=180мм H=45мм	0,2

III. Порядок доставки продукции к месту оказания услуг: дос
IV. Порядок возврата продукции Заказчику: доставка силами

Приложение – Технические требования на 1 листе.

Исполнитель:

ОИЯИ



Соглашение о сотрудничестве
№ 160
между

Объединенным институтом ядерных исследований,
Адрес: Россия, 141980, Московская область, г. Дубна, ул. Жолио-Кюри, 6,
В лице:
Должность: Директор
Имя: Трубников Григорий Владимирович
Основание полномочий: Устав
далее именуемым «ОИЯИ»,
и

АО «Микрон»
Адрес: 124460, г. Москва. Зеленоград, ул. Академика Валиева, дом 6, стр. 1
В лице:
Должность: Главный конструктор АО «Микрон»
Имя: Шмаков Евгений Вячеславович
Основание полномочий: Доверенность № 06/2023 от 01 февраля 2023г.
Далее именуемым «Участник»,

В дальнейшем при совместном упоминании ОИЯИ и Участник именуются «Стороны», а по отдельности «Сторона».

о следующем:

1. Сотрудничество

Настоящее Соглашение определяет общие условия, а также основные направления
дничества между Сторонами в рамках:
ика сотрудничества: Ионное облучение полупроводниковых пластин
согласно Проблемно-тематическому плану ОИЯИ (при наличии): ***03-4-1128-2017/2023***
едования взаимодействия нейтронов с ядрами и свойств нейтрона».
трудничества:
золированным
ния пучками

Training is planned within the framework of the industrial technological cycle of batches of silicon wafers for the production of power electronics.

Project with JSC SNIP (Rosatom State Corporation)

МЕЖДУНАРОДНАЯ МЕЖПРАВИТЕЛЬСТВЕННАЯ ОРГАНИЗАЦИЯ
INTERNATIONAL INTERGOVERNMENTAL ORGANIZATION

ОБЪЕДИНЕННЫЙ ИНСТИТУТ ЯДЕРНЫХ ИССЛЕДОВАНИЙ
JOINT INSTITUTE FOR NUCLEAR RESEARCH

ул. Жолио-Кюри 6, г. Дубна, Московская область, Россия, 141980 6, Joliot-Curie St, Dubna, Moscow Region, Russia, 141980
Tel.: +7 (496) 216-50-59 Fax: +7 (495) 632-78-80 AT: 205493 WOLNA RU E-mail: post@jinr.ru http://www.jinr.ru

21.09.2023 № 010-36/1178
на № 50-5000/8510 от 20.09.2023

Первому заместителю генерального директора по научной работе - главному конструктору Акционерного общества «Специализированный институт приборостроения» (АО «СНИИП»)

Чебышову С.Б.

Уважаемый Сергей Борисович!

В ответ на письмо №50-5000/8510 от 20.09.2023 «О запросе технико-коммерческого предложения» на выполнение работ по исследованию зависимости чувствительности устройства детектирования УДКН-04Р от энергии нейтронов, согласно предоставленному Техническому заданию (Приложение №1 к запросу), высылаем технико-коммерческое предложение.

Указанные в ТЗ работы по исследованию зависимости чувствительности устройства детектирования УДКН-04Р от энергии нейтронов, включая экспериментальные исследования и математические расчеты, могут быть выполнены сотрудниками ЛНФ ОИЯИ в течение 4 (четырех) месяцев с момента предоставления испытательного оборудования и технической документации после подписания Договора.

Срок действия настоящего ТКП – 90 календарных дней с даты подачи предложения.

Оплата 100% по факту выполнения работ.

Расчетная стоимость работ приведена в табл.1.

Таблица 1

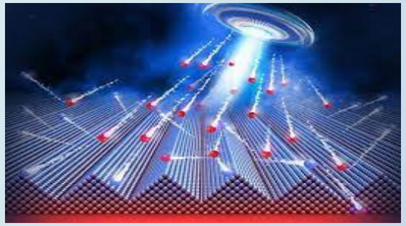
2. New installations planned for production

Microbeam capabilities

Methodological and technological capabilities:

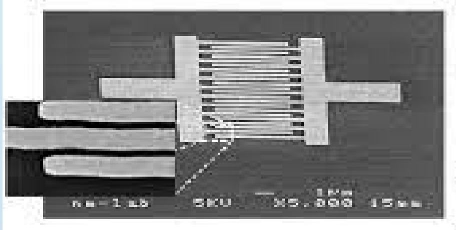
1. Precision studies of elemental depth profiles (1 ppm) with a step of 1 microns (two-dimensional distribution of elements / mapping) without destruction of the sample :

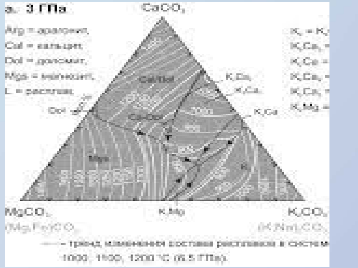
- IBA of planar objects with an area of less than 0.1 mm^2;
- IBA of objects with a rough surface (powder objects, etc.);
- scanning transmission ion microscopy (STIM);
- measurement of ion beam induced charge (IBIC) in semiconductors.



2. Direct proton beam Exposure (PBW):

- proton lithography,
- creation of small 3D nanostructures (electronic nanotechnology);
- physical (phase transformations) and chemical modification (chemical reduction) of localized areas of samples at a strictly defined depth (microelectronics, photonics etc.).

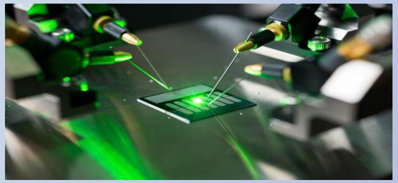




The prospects:

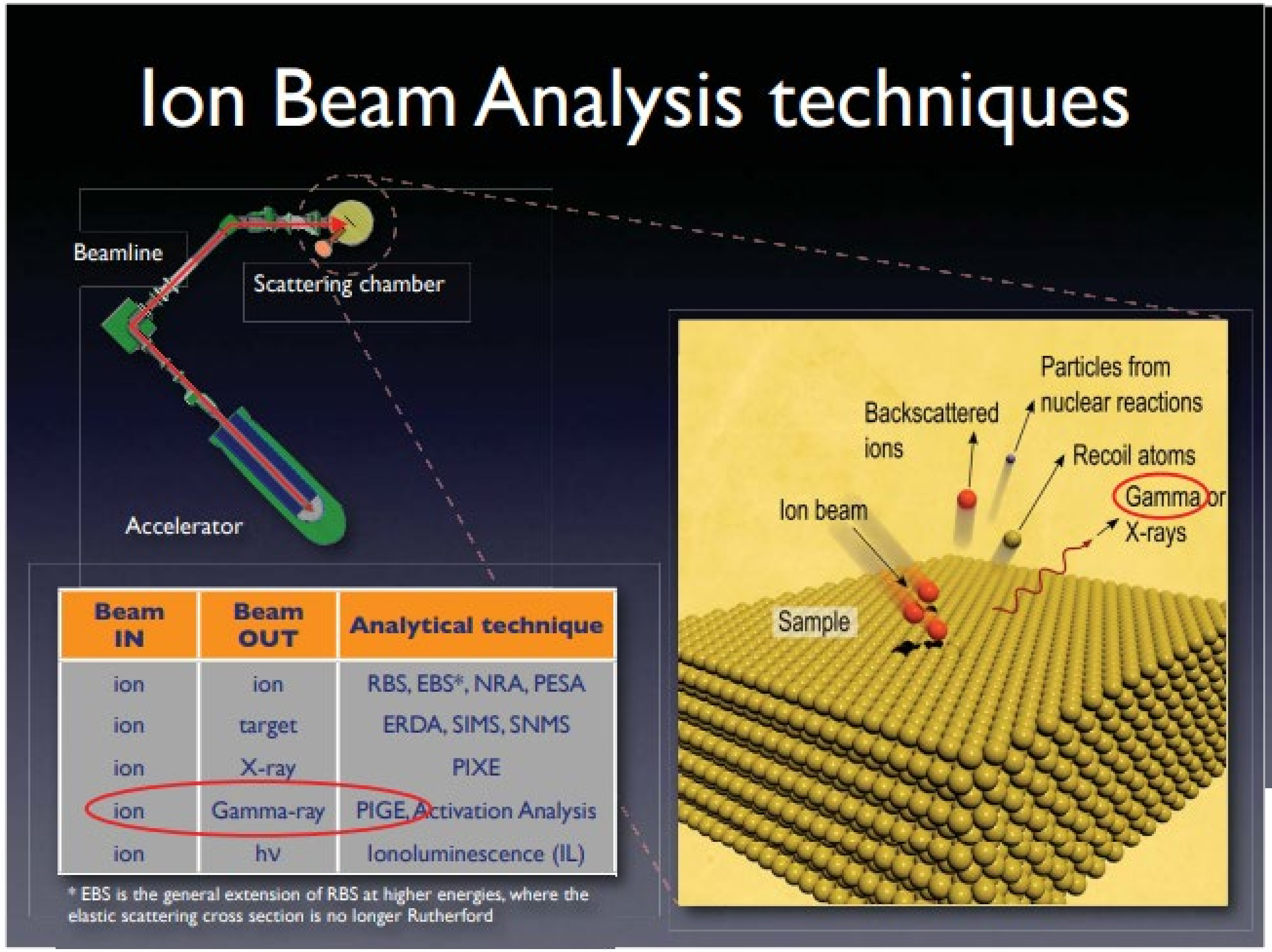
Determination of small concentrations of elements in local zones (1 ppm at ~1 microns):

- zones of segregation of impurities in structural materials under operating loads;
- definition of diseases [2];
- cancer cell research [3];
- study of geological samples;
- effects caused by single events (SEE - Single Event Effect) [4,5];
- The possibility of obtaining nanocomponents (electronics) with a high aspect ratio (160:1), which allows us to consider such a structure as essentially three-dimensional:
- local exposure of organoids.



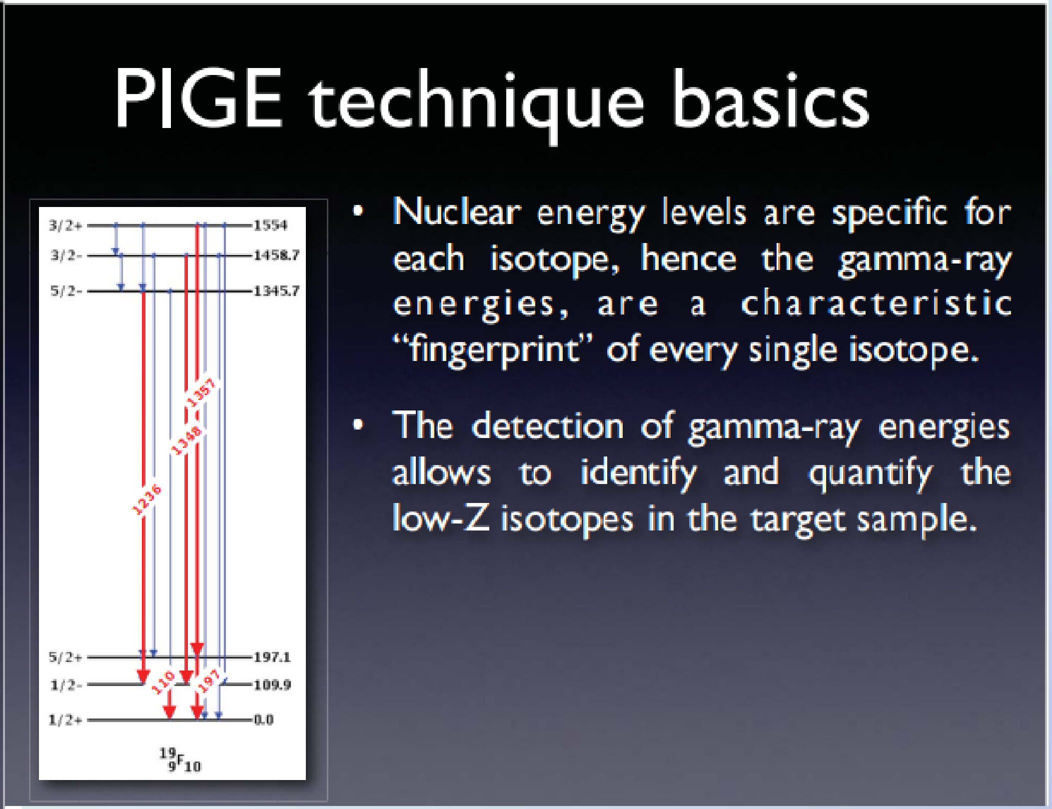
[1] A.G. Ponomarev NUCLEAR SCANNING MICROPROBE: THE CURRENT STATE IN THE WORLD, FIELDS OF APPLICATION AND PROSPECTS OF DEVELOPMENT // 9th International Conference "Interaction of radiation with a solid body", September 20-22, 2011, Minsk, Belarus pp.438-440,
[2]. Barapatre N., Morawski M., Butz T. et al. // Nucl. Instr. and Meth. B. – 2010. - Vol. 268. - P. 2156.
[3]. Kirkby K.J., 260. - P. 97.
[4]. Watt F., van Kan J.A., Rajta I. et al. // Nucl. Instr. and Meth. B. – 2003. - Vol. 210. - P. 14.
[5]. Spemann D., Reinert T., Vogt J. et al. // Nucl. Instr. and Meth. B. – 2002. - Vol. 190. - P. 312.

Particle Induced Gamma-ray Emission (PIGE) - Method



Beam IN	Beam OUT	Analytical technique
ion	ion	RBS, EBS*, NRA, PESA
ion	target	ERDA, SIMS, SNMS
ion	X-ray	PIXE
ion	Gamma-ray	PIGE, Activation Analysis
ion	hv	Ionoluminescence (IL)

* EBS is the general extension of RBS at higher energies, where the elastic scattering cross section is no longer Rutherford



General features of IBA

• Multielemental • Quantitative analysis • High sensitivity (1-100 ppm in at/cm^3; 10^{11}-10^{12} in at/cm^2) • Surface analysis (10 Å - 10 mkm) • Depth pro filing • Non-destructive • No sample pre-treatment • Microanalysis (lateral resolution

Other promising options

3. Positronic annihilation
4. Atmospheric RBS module

Promising areas of work

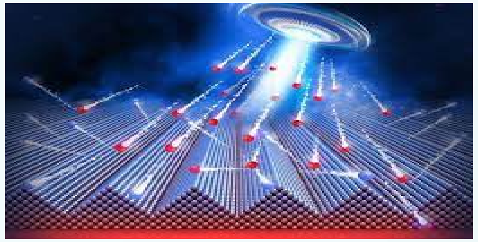
Area of interest:

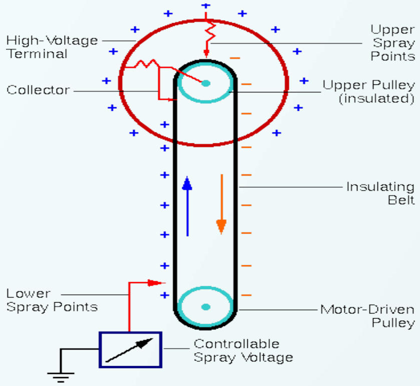
- powder nanotechnology;
- ion implantation nanotechnology;
- renewable energy;
- direct and alternating current electrical measurements;
- dimensional effects in dielectric nanoparticles;
- Radiation materials science;
- ion beam analysis.

Developed areas:

- Ion beam analysis;
- Ion beam nanotechnology;
- Adsorption hydropower;
- Electronics based on new physical principles (homogeneous electronics, nanoionic capacitors);

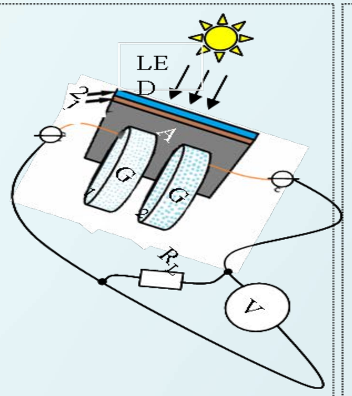
Conclusion



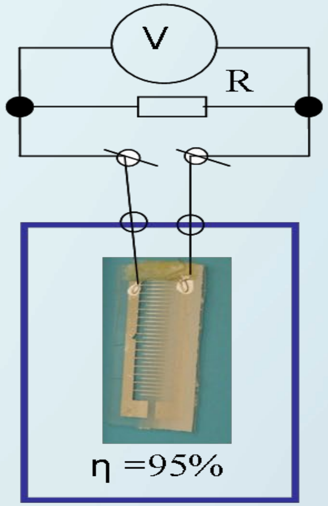


Accelerator ion beam technologies

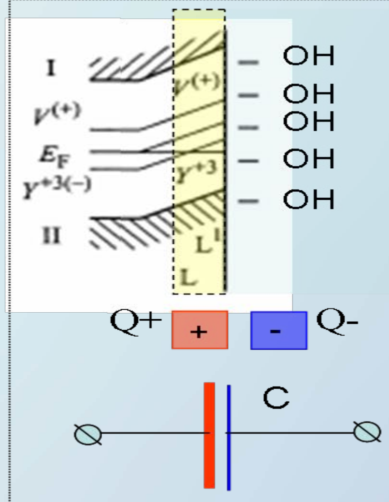
Radioisotope energy source



Optoelectronic transistor



Chemo-electronic converter



Nano-ionic capacitor

We invite all interested parties to cooperation!

Correspondence :
+79771985015
+79165002157
E-mail:doroh@jinr.ru
E-mail: doroskevich1977@gmail.com

Aleksandr Doroshkevich
Head of group “Installation of EG-5”
FLNP JINR

Thank you for your attention.

JOINT INSTITUTE FOR NUCLEAR RESEARCH

Кооперация с МИФИ

FRANK LABORATORY OF NEUTRON PHYSICS

Prof. Lagov P.B.
NRNU MEPhI

1. A Y Polyakov, V I Nikolaev, A I Pechnikov, P B Lagov, I V Shchemerov, A A Vasilev, A V Chernykh, A I Kochkova, L Guzilova, Yu S Pavlov, T V Kulevoy, A S Doroshkevich, R Sh Isaev, A V Panichkin and S J Pearton Carrier removal rates in 1.1 MeV proton irradiated α-Ga2O3 (Sn) To cite this article: A Y Polyakov et al 2023 **J. Phys. D: Appl. Phys.** 56 305103 **DOI 10.1088/1361-6463/acd06b (Q1, IF= 3.409).**
2. Ivan Schemerov, A.Ya. Polyakov, P. B. Lagov, V. D. Kirilov, Svetlana Kobeleva, A. I. Kochkova, Yu. O. Kulanchikov, O. S. Doroshkevich. The effect of trapping sites introduced by 1 MeV proton irradiation on the reverse current recovery time in Ga2O3-based Schottky diodes. **Industrial laboratory Diagnostics of materials** 89(7):25-33 July 2023 **DOI:** 10.26896/1028-6861-2023-89-7-25-33 **(Q4, IF = 0,28)**
3. Polyakov, A. Y., Vasilev, A. A., Kochkova, A. I., Shchemerov, I. V., Yakimov, E. B., Miakonkikh, A. V., Chernykh, A. V., Lagov, P. B., Pavlov, Y. S., Doroshkevich, A. S., Isaev, R. S., Romanov, A. A., Alexanyan, L. A., Matros, N., Azarov, A., Kuznetsov, A., &Pearton, S. (2024). Proton damage effects in double polymorph γ/β-Ga2O3 diodes. **Journal of Materials Chemistry C**, 12(3), 1020–1029.https://doi.org/10.1039/D3TC04171A **(Q1, IF – 5.7).**

Поверхностные уровни. Представление Зейтца

β-ZrO_2
(YSZ)

ОПЗ длиной L

$$L = [\varepsilon\varepsilon_0 kT/(e^2 n)]^{1/2}.$$

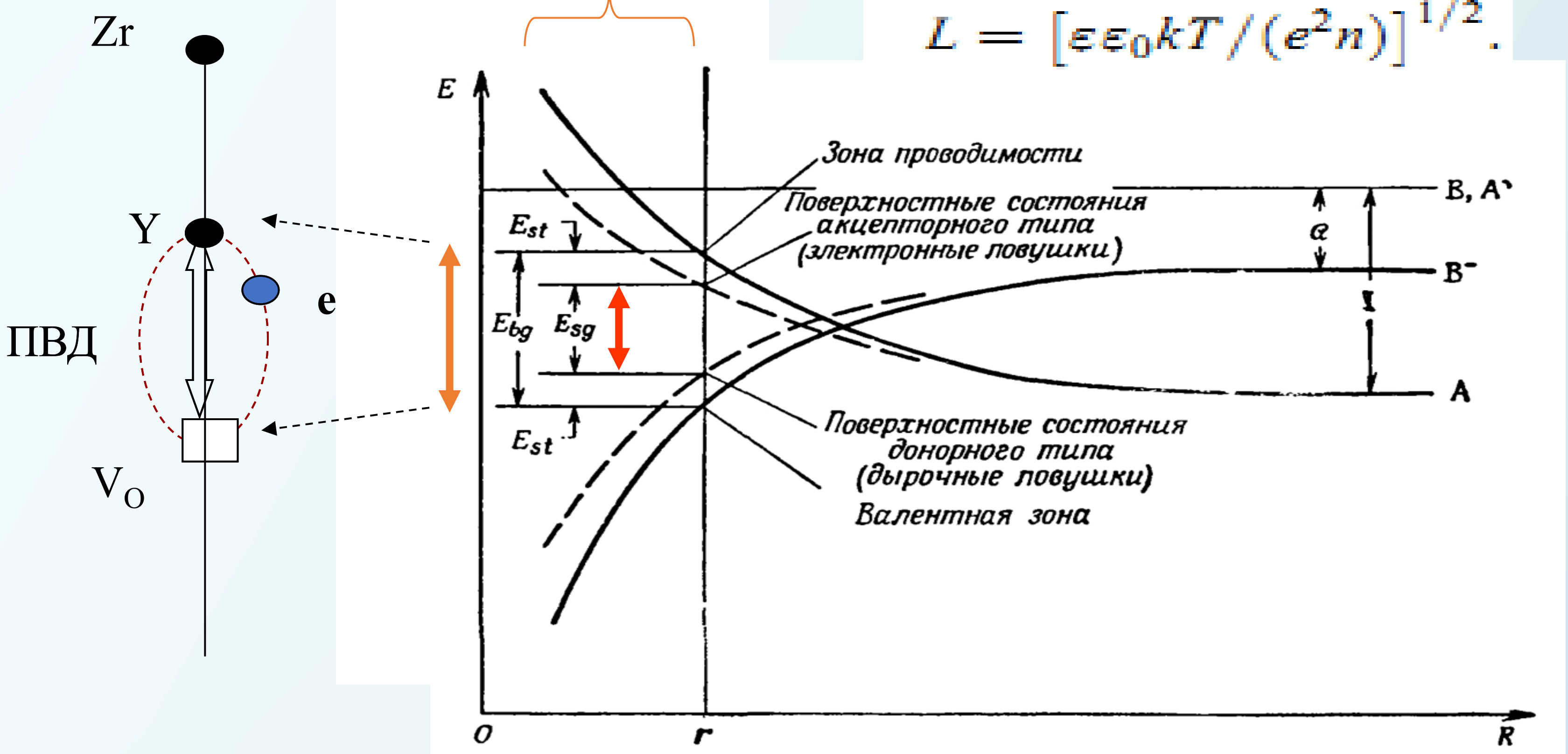


Fig. 1. Energy levels as a function of interatomic distance R in AB ionic crystals.

$$E_{bg} = 2V_b - I + a$$

$$E_{sg} = 2V_s - I + a$$

$$E_{st} = \frac{E_{bg} - E_{sg}}{2}$$

$$V_l = \frac{c_l e z}{r}, \quad l = b \text{ или } s$$

Where V_l is the energy of Madelung

$$c_b = \sum_{i,j,k} \frac{q_{ijk}}{R_{ijk}} = \sum_{i,j,k} Q \qquad c_s = \sum_{i \geq 0, j, k} Q$$

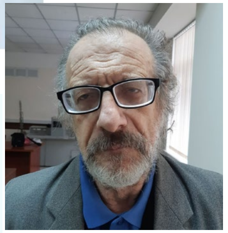
Зейтс показал, что ширина запрещенной зоны зависит от энергия Маделунга.
Энергия Маделунга различна для объемных тел и поверхности.

.

[1] Oksengendler BL, Turaeva NN, Kh. Ashirmetov A, Ivanov NV, Karpova OV, Maksimov SE, Pelenovich VO. Kh. B. Ashurov. Nanofractals, their properties and applications. In Horizons in World Physics, (Ed. A. Reimer). – N.Y.: Nova Science Publishers. 2019; Ch.1: 1-36.

Варизонность ионных кристаллов

Z. I. Karimov



Проф. Б.Л. Оксенгендлер

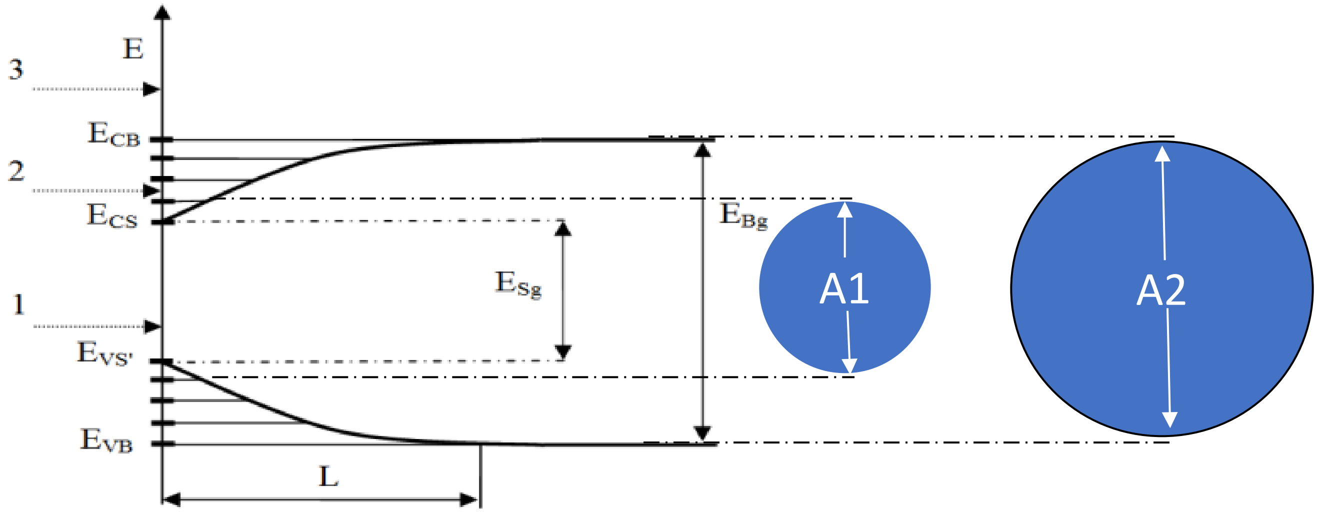


Fig. 2. Energy structure of the gradient gap of the near-surface zone of an ionic crystal with the parameters of the gradient gap (energy difference and depth), the diagram of the origin of surface local states (1, 2, 3 means the incidence of electron waves on the surface for various energy ranges and their derivatives when the wave functions free space and crystal coincide; within zone "1" states appear that are different from the Tamm states)

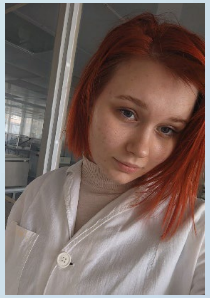
Для наночастиц ионных кристаллов, размеры которых такие, что $E<E_{SB}$, работа выхода электронов **A** будет зависеть от размера частиц ввиду зависимости от размера частиц ширины ЗЗ.

В статье [1], основанной на переосмыслении схемы Зайтца (1940), предлагается новая концепция электронной структуры границ раздела (включая поверхность) кристаллов с ионной связью. **Показано, что кулоновское дальнодействие преобразует обычную структуру с уровнями Тамма в группу локальных уровней нового типа**. Полученные результаты оказались очень полезными для решения ряда задач в наноэлектронике.

[1] Z. I. Karimov, B. L. Oksengendler, S. Kh. Suleymanov, A. S. Doroshkevich, A. F. Zatsepin, N. N. Nikiforova and N. A. Kulagina Varisonality and Surface Levels in Crystals with an Ionic Bond / Chapter 7 in book Research Highlights in Science and Technology Vol. 1. Pp. 130-150. doi: 10.9734/bpi/rhst/v1/5397E.

Nanotechnology. Electronics based on new physical principles

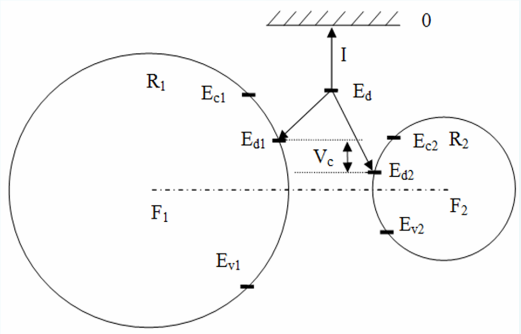
The rectifying contact of hydrated different sizes YSZ - nanoparticles



Жанна Мезенцева

Анна Захарова

Theory



$$V_c = -1/2(E_{d1} - E_{d2}) \neq 0$$

$$E_d = \frac{1}{2} E_g \left[1 - 2me^4 / E_g \xi^2 \hbar^2\right]^{1/2}$$

Fig.1. The schematic interpretation of the effect of the rectifying contact, where, m and e are the mass and charge of the electron, ξ is the dielectric constant [2].

[1] B.R. Kutlimurotov, **B.L. Oksengendler** et al., Uzbek Journal of Physics, Vol. 24, No. 4, pp. 254-262, 2022. doi.org/10.52304/.v24i4.378.

[2] K.L. Keldysh, Soviet Physics JETF, 1964, 18, 1, 253

Experiment

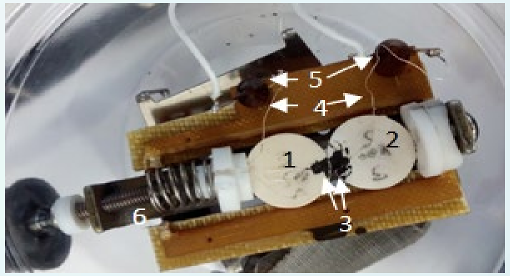


Fig.2. Experimental setup.
1, 2-compacts under study;
3-contact pads;
4-current collectors;
5-locking racks6-spring loaded clamp.

Operating Parameter \ Composition	ZrO_2	ZrO_2+3%Y_2O_3	ZrO_2+3%Y_2O_3
Maximum reverse voltage, V	>6	-0,5±0,1	>6
Maximum reverse current, μA	5±5	70±10	5±5
Maximum forward voltage, V	5±0,5	5,5±0,5	5±0,5
Maximum reverse current, μA	5±5	250±5	250±5

[3] A.S. Doroshkevich, B.L. Oksengendler et al., Nanomaterials 2022, 12, 4493. doi.org/10.3390/nano12244493.

Result

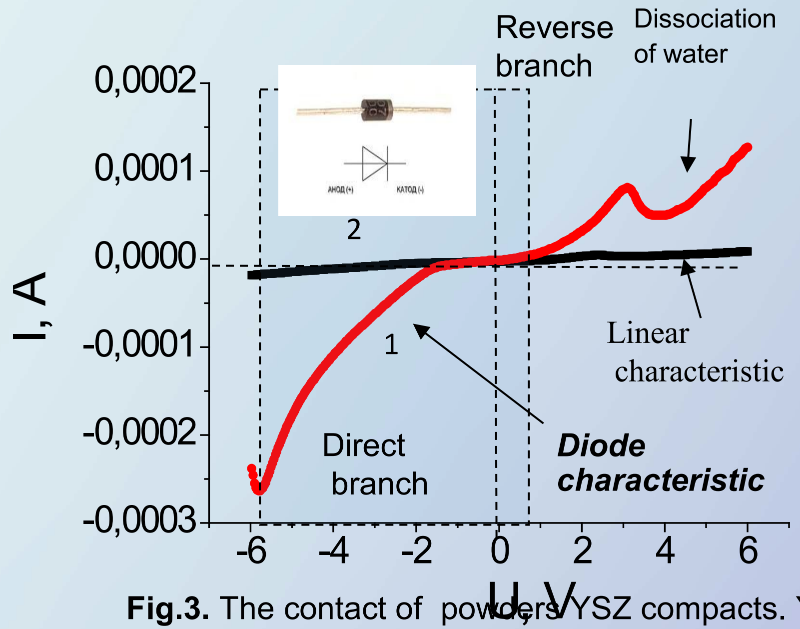
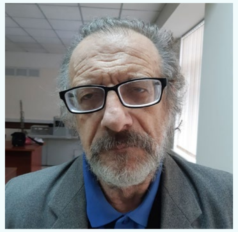


Fig.3. The contact of powders YSZ compacts. YSZ = ZrO_2 – x mol%Y_2O_3 (x = 0. 3, 8). The annealing temperatures of the powders are 400℃ and 500℃. The particle sizes are 7.5 and 9 nm, respectively.

Случай искривленной поверхности



Проф. Б.Л. Оксенгендлер

β-ZrO_2 (YSZ)

Ненасыщенные валентные орбитали имеют угловое распределение

Следовательно, имеет место спектр электронных состояний вблизи поверхностных уровней Шокли / Тамма

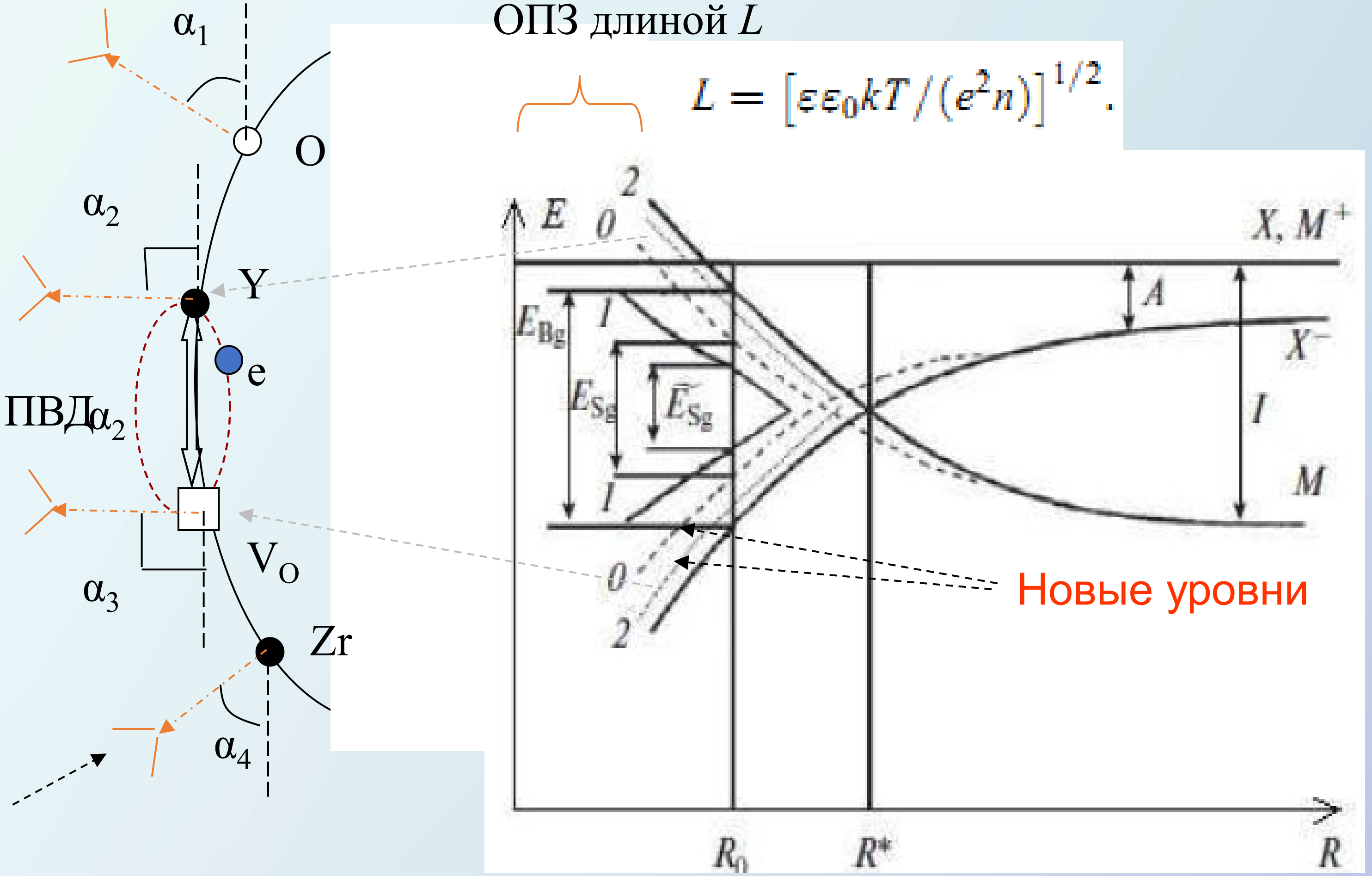


Fig. The mechanism for controlling the electronic spectrum of the near-surface region using the curvature of the surface.

[1] Oksengendler BL, Turaeva NN, Kh. Ashirmetov A, Ivanov NV, Karpova OV, Maksimov SE, Pelenovich VO. Kh. B. Ashurov. Nanofractals, their properties and applications. In Horizons in World Physics, (Ed. A. Reimer). – N.Y.: Nova Science Publishers. 2019; Ch.1: 1-36.

Влияние изгиба поверхности на Активность химических центров на поверхности

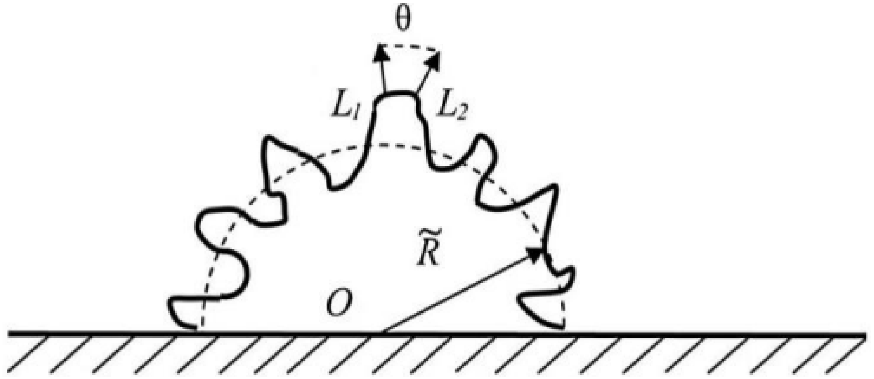


Figure 9. Diagram of directions of neighboring Tamm orbitals (L_1 and L_2), differing by angle θ , hemispherical nanoparticle in case of its rough (fractal) surface.

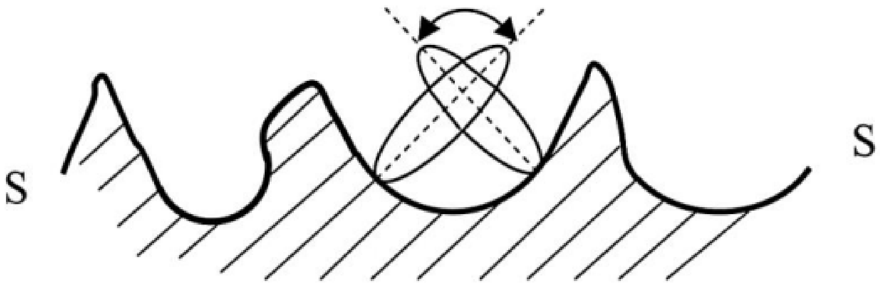


Figure 10. Passivation of surface S due to the chemical-bond saturation at neighboring Tamm orbitals in the concave regions.

1. Искривление поверхности существенно изменяет зонную структуру наноматериалов.
2. Направленно изменяя топологию поверхности наночастиц возможно управлять их реакционной способностью и избирательностью по отношению к химическим элементам (изменять электронное сродство).

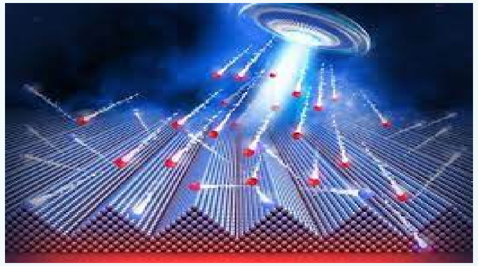
[1] Oksengendler BL, Turaeva NN, Kh. Ashirmetov A, Ivanov NV, Karpova OV, Maksimov SE, Pelenovich VO. Kh. B. Ashurov. Nanofractals, their properties and applications. In Horizons in World Physics, (Ed. A. Reimer). – N.Y.: Nova Science Publishers. 2019; Ch.1: 1-36.

Project: Modernization of EG-5

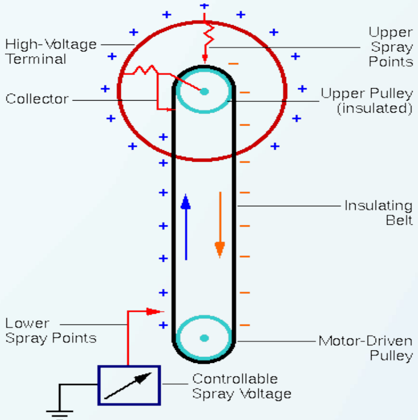
Significant advantage:

- high energy stability of ion beam;
- high intensity of ion beam;
- accelerated particles (H^+, He^+, D^+);
- accelerated voltage (from 800 keV to 3MeV).
- possibility of obtaining of high-intensity ion beams.

Areas of use:



- Nuclear reactions with fast quasimonoenergetic neutrons;
- Ion Beam Spectrometry (Multilayer structures, isotope determination, elemental depth profiling);
- Radiation technologies (Science, technology, medicine, etc.).



Ion beam parameters

- Range of ion beam currents - 0,01 - 3 мкА (**100 – 150mkA***);
- Real ion beam energy range - 900 keV – 2,5MeV (**4,1 MeV***);
- Energy resolution (H^+, He^{2+}) - not worse than 15keV;
- Charged particles flow (H^+, He^{2+}) – 10^{12}–10^{13} part /s sm^{-2}
-Neutrons flow – 5 10^7 pat/s sm^2
- Max. neutrons energy - 5,5±0,1 MeV (Deutron current – 2mkA, deutron energy – 2,5MeV);

*- will be aftermodernization

Methods of modification and testing of Si-plates

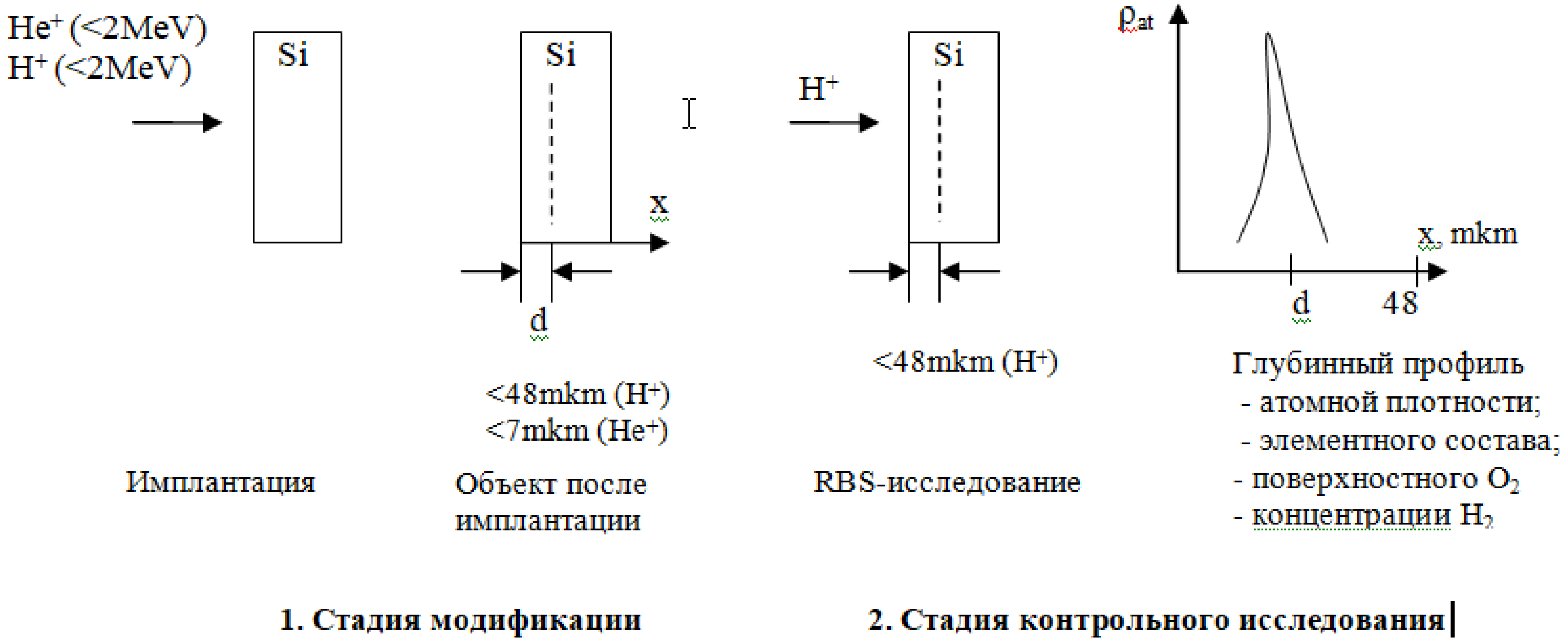


Рис. 4. Схематическое представление модификации Si - материалов ионами легких газов и бесконтактного неразрушающего контроля пространственного расположения модифицированного участка и плотности имплантированных ионов в объеме материала с помощью лучевых методов ЭСУ ЭГ-5.

on beam technologies allow both the physical modification of Si materials by an ion beam and the study of the effects of radiation exposure.

Кооперация с МИФИ

Prof. Lagov P.B.
NRNU MEPhI

1. A Y Polyakov, V I Nikolaev, A I Pechnikov, P B Lagov, I V Shchemerov, A A Vasilev, A V Chernykh, A I Kochkova, L Guzilova, Yu S Pavlov, T V Kulevoy, A S Doroshkevich, R Sh Isaev, A V Panichkin and S J Pearton Carrier removal rates in 1.1 MeV proton irradiated α-Ga2O3 (Sn) To cite this article: A Y Polyakov et al 2023 **J. Phys. D: Appl. Phys.** 56 305103 **DOI 10.1088/1361-6463/acd06b** **(Q1, IF= 3.409).**
2. Ivan Schemerov, A.Ya. Polyakov, P. B. Lagov, V. D. Kirilov, Svetlana Kobeleva, A. I. Kochkova, Yu. O. Kulanchikov, O. S. Doroshkevich. The effect of trapping sites introduced by 1 MeV proton irradiation on the reverse current recovery time in Ga2O3-based Schottky diodes. **Industrial laboratory Diagnostics of materials** 89(7):25-33 July 2023 **DOI:** 10.26896/1028-6861-2023-89-7-25-33 **(Q4, IF = 0,28)**
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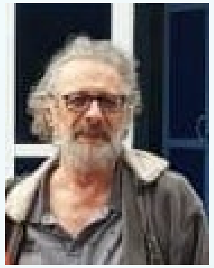
Team



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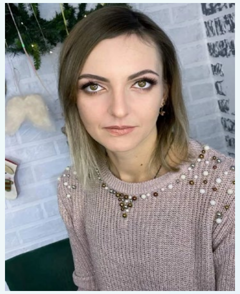

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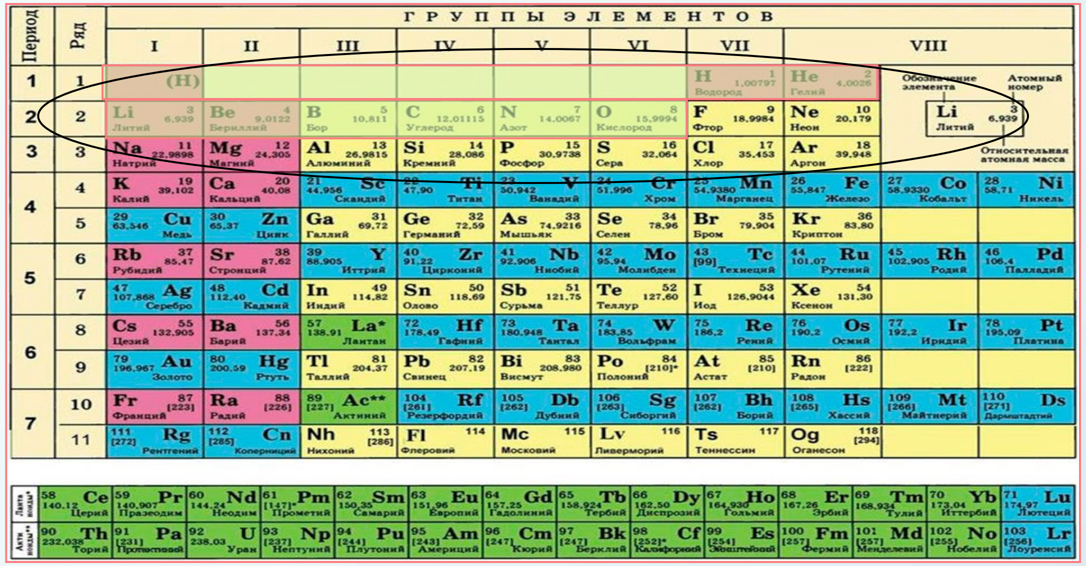
PGAA facility for determining the Elemental composition of materials using EG-5

JOINT INSTITUTE FOR NUCLEAR RESEARCH
FRANK LABORATORY OF NEUTRON PHYSICS

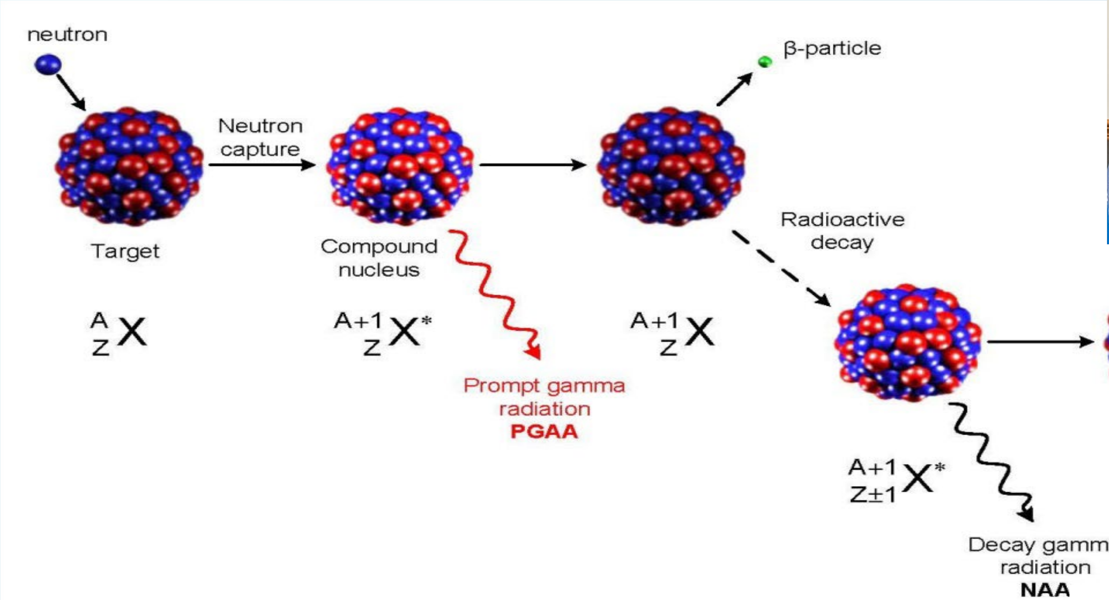
We planned to create the following research areas and develop promising works:

Main advantages

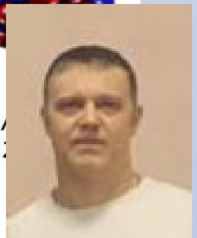
- *Lack of residual activity in samples, the ability to examine samples in the future (which is very important in the case of expensive items)*
- *Both directions, unique for JINR and the Russian Federation, will add to the spectrum of available NAA methods at JINR.*



- Determination of the elemental composition by the reaction of inelastic neutron scattering.



К. Храмко



И. А. Чепурченко

PGAA complements existing methods of analysis by working with the determination of isotopes of light particles, combining all the advantages of the described methods, such as: completely indestructible sample, simple sample preparation, as well as an extremely low degree of activation with the possibility of further work with the material.

Nuclear Data High Priority Request List

ID	View	Target	Reaction	Quantity	Energy range	Sec.E/Angle	Accuracy	Cov	Field	Date
2H		8-O-16	(n,a),(n,abs)	SIG	2 MeV-20 MeV		See details	Y	Fission	12-SEP-08
3H		94-PU-239	(n,f)	prompt g	Thermal-Fast	Eg=0-10MeV	7.5	Y	Fission	12-MAY-06
4H		92-U-235	(n,f)	prompt g	Thermal-Fast	Eg=0-10MeV	7.5	Y	Fission	12-MAY-06
8H		1-H-2	(n,el)	DA/DE	0.1 MeV-1 MeV	0-180 Deg	5	Y	Fission	16-APR-07
15H		95-AM-241	(n,g),(n,tot)	SIG	Thermal-Fast		See details		Fission	10-SEP-08
18H		92-U-238	(n,inl)	SIG	65 keV-20 MeV	Emis spec.	See details	Y	Fission	11-SEP-08
19H		94-PU-238	(n,f)	SIG	9 keV-6 MeV		See details	Y	Fission	11-SEP-08
21H		95-AM-241	(n,f)	SIG	180 keV-20 MeV		See details	Y	Fission	11-SEP-08
22H		95-AM-242M	(n,f)	SIG	0.5 keV-6 MeV		See details	Y	Fission	11-SEP-08
25H		96-CM-244	(n,f)	SIG	65 keV-6 MeV		See details	Y	Fission	12-SEP-08
27H		96-CM-245	(n,f)	SIG	0.5 keV-6 MeV		See details	Y	Fission	12-SEP-08
29H		11-NA-23	(n,inl)	SIG	0.5 MeV-1.3 MeV	Emis spec.	See details	Y	Fission	12-SEP-08
32H		94-PU-239	(n,g)	SIG	0.1 eV-1.35 MeV		See details	Y	Fission	12-SEP-08
33H		94-PU-241	(n,g)	SIG	0.1 eV-1.35 MeV		See details	Y	Fission	12-SEP-08
34H		26-FE-56	(n,inl)	SIG	0.5 MeV-20 MeV	Emis spec.	See details	Y	Fission	12-SEP-08
35H		94-PU-241	(n,f)	SIG	0.5 eV-1.35 MeV		See details	Y	Fission	12-SEP-08
37H		94-PU-240	(n,f)	SIG	0.5 keV-5 MeV		See details	Y	Fission	15-SEP-08
38H		94-PU-240	(n,f)	nubar	200 keV-2 MeV		See details	Y	Fission	15-SEP-08
39H		94-PU-242	(n,f)	SIG	200 keV-20 MeV		See details	Y	Fission	15-SEP-08
41H		82-PB-206	(n,inl)	SIG	0.5 MeV-6 MeV		See details	Y	Fission	15-SEP-08
42H		82-PB-207	(n,inl)	SIG	0.5 MeV-6 MeV		See details	Y	Fission	15-SEP-08
45H		19-K-39	(n,p),(n,np)	SIG	10 MeV-20 MeV		10	Y	Fusion	11-JUL-17
97H		24-CR-50	(n,g)	SIG	1 keV-100 keV		8-10	Y	Fission	05-FEB-18
98H		24-CR-53	(n,g)	SIG	1 keV-100 keV		8-10	Y	Fission	05-FEB-18
99H		94-PU-239	(n,f)	nubar	Thermal-5 eV		1	Y	Fission	12-APR-18
102H		64-GD-155	(n,g),(n,tot)	SIG	Thermal-100 eV		4	Y	Fission	09-MAY-18
103H		64-GD-157	(n,g),(n,tot)	SIG	Thermal-100 eV		4	Y	Fission	09-MAY-18
114H		83-BI-209	(n,g)Bi-210g,m	BR	500 eV-300 keV		10	Y	ADS,Fission	09-NOV-18
115H		94-PU-239	(n,tot)	SIG	Thermal-5 eV		1	Y	Fission	08-APR-19

Most of the required neutron energies are in the range, which can be achieved in our accelerator. These tasks are difficult and expensive to solve at other types of neutron facilities.

[2] https://www.oecd-nea.org/dbdata/hprl/search.pl?vhp=on

Другие публикации за 2024г

1. Phan Luong Tuan, Mirsolaw Kulik, Marius Stef, Tran Van Phuc, Nguyen Thi Bao My, Tatyana Yuryevna Zelenyak, Gabriel Buse, Andrei Racu, Aleksandr Doroshkevich, Le Hong Khiem, Vu Duc Cong, Andriy Igorevych Lyubchyk, Sergiy Igorevich Lyubchyk, Svitlana Borisovna Lyubchyk, Nguyen Ngoc Anh. An examination on the porosity of ErF3 doped CaF2 crystal using the Rutherford back-scattering method. Nuclear Instruments and Methods in Physics Research Section B: Beam Interactions with Materials and Atoms. Volume 547, February 2024, 165178, https://doi.org/10.1016/j.nimb.2023.165178. **(Q3, IF=1,4)**
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3. L. M. Ledo Pereda, V. N. Semenov, V. S. Rikhvitsky, A. N. Likhachev, R. Sh. Isaev, I. A. Chepurchenkoa, A. S. Doroshkevich, V. A. Alexandrov Ion Beam Scanning System for EG-5 Accelerator // Physics of Particles and Nuclei Letters, 2024, Vol. 21, No. 4, pp. 938–945, 2024. DOI: 10.1134/S1547477124701061 **(Q3, IF=0,3)**
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11. Isayev R., Natalia P., Evgeniy M., Dzhumaev P., Korenevski E. Corrosion of EP823 steel cladding under heavy liquid metal coolant reactor conditions: A review// **Nuclear Science and Engineering**https://doi.org/10.1080/00295639.2024.2383110
12. Р.Ш. Исаев, П.С. Джумаев «Взаимодействие хромового покрытия с оболочкой твэла из стали ЭП823-Ш в диапазоне температур 420-650 оС // **Вестник НИЯУ МИФИ**. – 2024. – Т. 13. – №. 4.
13. Р.Ш. Исаева, П.С. Джумаева, М.В. Леонтьева-Смирновой, И.А. Науменко «Коррозионные свойства хромового покрытия на внутренней поверхности оболочки твэла из ферритно-мартенситной стали ЭП823 // **Вопросы атомной науки и техники. Серия: Материаловедение и новые материалы**– 2024 – №2(123).

13 публикаций в рецензируемых журналах без IF

Устные доклады в 2024

1. **Aleksandr Doroshkevich**, Zhanna Mezentseva, Boris Oksengendler, Sultan Suleymanov, Ekaterina Didenko, Odilkhoja Parpiev ADVANCED NUCLEAR PHYSICS AND NANOTECHNOLOGICAL RESEARCH ON THE BASE OF THE EG-5 ACCELERATOR AT JINR // Third International Forum “Physics -2024”, Samarkand State University and Institute of Engineering Physics Samarkand, Uzbekistan, April 23-25, 2024 (устный доклад).

2.Mezentseva Zh.V., Doroshkevich A.S., Oksengendler B.L., Kirillov A.K., Didenko E.A., Nikiforova N.N., Carmen Mita, Diana Mardare, Nicoleta Cornei, Suleimanov S.H., ParpievO.R. ELECTRICAL PROPERTIES OF INTERFACES OF HYDRATED MULTI-DIMENSIONAL YSZ NANOPOWDERS FOR PROMISING APPLICATIONS OF RENEWABLE ENERGY AND HOMOGENEOUS ELECTRONICS // Third International Forum “Physics -2024”, Samarkand State University and Institute of Engineering Physics Samarkand, Uzbekistan, April 23-25, 2024 (устный доклад).

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Conclusion

1. The technique has been developed that allows both the physical modification of Si materials by an ion beam and the study of the effects of radiation exposure.
2. It has been established that radiation treatment with light gas ions leads to the appearance of discontinuities in the volume of a single silicon crystal and, as a result, an increase in the specific density of the skin layer and an improvement in the dynamic characteristics of structures in pulsed modes and at high frequencies.
3. Irradiation of oxide nanoparticles with an ion beam is promising as a method of modifying their physical properties.
4. Impedance spectroscopy makes it possible to study changes in the electrical structure and electrical properties of semiconductor and nanostructured materials both as a result of radiation exposure and under changing external conditions.