# International Workshop on Biophysics and Materials at NICA

# Report of Contributions

https://indico.jinr.ru/e/biomat2016

Contribution ID: **0** Type: **not specified**

# Opening BIOMAT workshop

*Monday, 12 December 2016 08:00 (10 minutes)*

**Presenter:** Prof. KEKELIDZE, Vladimir (VBLHEP, JINR)

**Session Classification:** Opening session

Contribution ID: **1** Type: **not specified**

# Development of applied researches at NICA facility

*Monday, 12 December 2016 08:10 (30 minutes)*

In the talk will present the proposal on the roadmap for applied research development in the material science and radiobiology at NICA and the outline sketch of the first stage of experimental installations: 1 - for direct research of influence the high energy of protons and heavy ions with energy up to 0.8 GeV/n on the electronic equipment used in special equipment, space devices 2 - for researches on impact of protons and heavy ions on a biological objects and a materials.

**Primary author:** Prof. GOLUBEV, Alexander (FSBI ”SSC RF ITEP” of NRC ”Kurchatov Institute”)

**Presenter:** Prof. GOLUBEV, Alexander (FSBI ”SSC RF ITEP” of NRC ”Kurchatov Institute”)

**Session Classification:** Opening session

Contribution ID: **2** Type: **not specified**

# Present and future activities in material science at GSI&FAIR

*Monday, 12 December 2016 08:40 (30 minutes)*

Not submmited

**Primary author:** Prof. TRAUTMANN, Christina (GSI Helmholtzzentrum, Germany)

**Presenter:** Prof. TRAUTMANN, Christina (GSI Helmholtzzentrum, Germany)

**Session Classification:** Opening session

Contribution ID: **3** Type: **not specified**

# Instrumentation for materials research at high energy ion beam facilities

*Monday, 12 December 2016 09:10 (30 minutes)*

Not submmited

**Primary author:** Dr SEVERIN, Daniel (GSI Helmholtzzentrum, Germany)

**Presenter:** Dr SEVERIN, Daniel (GSI Helmholtzzentrum, Germany)

**Session Classification:** Opening session

Contribution ID: **4** Type: **not specified**

# Area of applied technologies and scientific infrastructure at the accelerator complex NICA

*Monday, 12 December 2016 10:05 (30 minutes)*

Area of applied technologies and scientific infrastructure at the accelerator complex NICA. The analysis of (We analyze) possible directions of applied research at the accelerator complex NICA using beams of different nuclei and different energies. For applied research, both in the F3 zone and on other channels has been developed and successfully operated a complex system of monitoring beams of accelerated particles. It is also designed spatial beam scanning system on the project with the raster of 100x100 mm. To study the structure of the irradiated objects such as inorganic and biological origin, developed optical diagnostic methods. On this basis, developed a confocal laser scanning microscope and CARS-microscope for biological objects. On established by the Joint Institute for Nuclear Research in RRC "Kurchatov Institute" energy dispersive EXAFS-spectrometer developed technique to study (method of research of), (research methodology for) radiation damage in condensed matter.

**Primary author:** Dr TYUTYUNNIKOV, Sergey (VBLHEP, JINR)

**Presenter:** Dr TYUTYUNNIKOV, Sergey (VBLHEP, JINR)

**Session Classification:** Opening session: Continue

Contribution ID: **5** Type: **not specified**

# Project NICA at JINR: construction, operation scenario, physics program and perspective applied research

*Monday, 12 December 2016 10:35 (30 minutes)*

Not submmited

**Presenter:** Dr TRUBNIKOV, Grigory (JINR)

**Session Classification:** Opening session: Continue

Contribution ID: **6** Type: **not specified**

# The "Radiation Barrier" for manned missions into deep space and NICA project

*Monday, 12 December 2016 12:30 (30 minutes)*

The concept of risk currently used when considering the idea of deep space flights is represented by a generalized dosimetric functional as the criterion and quantitative measure of the danger of space types of radiation. The generalized dose comprises the doses inducing the immediate and long-term effects. The immediate radiation-induced effects develop during the flight, while the long-term ones, during later life. To calculate the dose for the immediate and long-term effects of radiation exposure, the coefficients are introduced that express the influence of the following factors on the radiobiological effect: the quality of radiation (including protons and heavy charged particles of different energy), time distribution of the dose, human body distribution of the dose, and modification of the organism's radiation response due to other flight factors. As the immediate radiation exposure effects, considered are the disorders of marrow hematopoiesis, cutaneous covering, and other organs and tissues of the organism. Regulations usually associate the long-term effects of cosmonauts' radiation exposure with the development of neoplastic processes in the organism, the risk of tumor development being considered the main adverse consequence for the interplanetary flights. At the same time, it should be noted that heavy charged particles of the galactic cosmic rays (GCR) have a highly destructive effect on the biological structures – they have to be considered an extremely dangerous radiation factor that can cause crew's operator activity disorders already during the flight. This approach is supported by results of the experiments in which animals (rodents) were irradiated at charged particle accelerators at doses matching real fluxes of GCR heavy nuclei during a flight to Mars: in the post-irradiation period, disorders of spatial orientation and cognitive functions were observed (Rabin B. M. et al., 2004; Britten R.A. et al., 2012; PariharV.K. et al., 2015). The authors link these neurobiological effects to a glutamatergic synaptic transfer disorder – first of all, in hippocampus neurons. This is also indicated by the data showing a decrease in the level of a number of other neurotransmitters in different brain parts and behavioral reaction disorders in rodents after heavy ion irradiation (Stemberg A.S. et al., 2015). In experiments on 500 MeV/nucleon carbon ion irradiation of primates (Macaca mulatta) at a dose of 1 Gy, a reliable decrease of cognitive functions and the concentrations of metabolites (in particular, serotonin) was observed in animals of the excitable unbalanced type of higher nervous activity (Belyaeva et al., 2015). To take into account the high biological effectiveness of high-energy heavy charged particles in radiation risk evaluation for manned interplanetary flights, the concept of "the successful completion of the mission" was introduced (A.I. Grigoryev, E.A. Krasavin, M.A. Ostrovsky, 2015). Unlike the currently used radiation risk concept, which brings into the foreground the risk of cancer development – the long-term effects of the exposure, the new paradigm is concerned, first of all, with the risk of disorders of higher integrative functions of the crew members' central nervous system. These disorders can impair cosmonauts' operator functions already during the flight and endanger the successful completion of the mission. The possibility of using NICA accelerator complex to simulate the biological effect of cosmic radiation is discussed in the report.

**Primary author:** Prof. KRASAVIN, Eugene (LRB, JINR)

**Presenter:** Prof. KRASAVIN, Eugene (LRB, JINR)

**Session Classification:** Radiobiology session

Contribution ID: **7** Type: **not specified**

# Critical problems at modeling of heavy ion component in cosmic rays

*Monday, 12 December 2016 13:00 (30 minutes)*

Not submmited

**Primary author:** Prof. PANASYUK, Mikhail (SINP, MSU)

**Presenter:** Prof. PANASYUK, Mikhail (SINP, MSU)

**Session Classification:** Radiobiology session

Contribution ID: **8** Type: **not specified**

# Heavy ions in therapy and space

*Monday, 12 December 2016 13:30 (30 minutes)*

Heavy ion biophysics is an emerging research field with two main applications: cancer radiotherapy and space radiation protection. Both fields are rapidly growing. Particle therapy is generally acknowledged as a cutting edge methodology, and solid plans for the first heavy ion therapy center are established in USA within the cancer moonshot program. On the other hand, the commitments of the space agencies toward exploration make urgent to tackle the problem of radiation exposure, a potential showstopper for manned colonization of the Solar system.
Both particle therapy and space radiation fields share many common topics, and we will give three examples: light flashes, radiation-induced carcinogenesis, and hibernation. We will argue that ground-based accelerator research is essential for solving both problems.

**Primary author:** Prof. DURANTE, Marco (TIFPA-INFN, Italy)

**Presenter:** Prof. DURANTE, Marco (TIFPA-INFN, Italy)

**Session Classification:** Radiobiology session

Contribution ID: **9** Type: **not specified**

# Radiofrequency radiation effects in biomedical applications

*Monday, 12 December 2016 14:00 (25 minutes)*

We review our recently obtained data on developing the model of the interaction of spherical colloidal nanoparticles with low-frequency electromagnetic waves. The aim was to describe quantitatively the interaction of NP-electrolyte system with low-frequency electromagnetic waves for medical applications. We consider the RF heating of a nanoparticle immersed into the electrolyte solutions of varied conductivity. The proposed model allowed us to successfully describe the previously observed effect of strong heating of aqueous suspension of Si and Au NPs under RF irradiation with frequencies varied from 0.1 MHz to 500 MHz. We focused only on the description of heating in MHz region and did not take into account the dielectric losses in water. Our phenomenological analysis shows that presence of NPs can significantly affect the RF heating, especially at low electrolyte conductivities. The model explains the heating dependence on frequency of electromagnetic waves. We also found that optimum particle conductivity for maximum heating is located in range 0.1-1 Sm/m at 30 MHz and -50 mV zeta-potential, while the NP size shows quite insignificant impact on the heating. It should be noted that the observed weak dependence of the RF radiation-induced heating efficiency on conductivity of employed nanoparticle-based sensitizers is a pleasant surprise, which can opens up novel avenues for the development of mild cancer treatment modalities based on the employment of RF radiation.

**Primary author:** Prof. ZAVESTOVSKAYA, Irina (NRNU MEPhI)

**Presenter:** Prof. ZAVESTOVSKAYA, Irina (NRNU MEPhI)

**Session Classification:** Radiobiology session

Contribution ID: **10** Type: **not specified**

# Experience in hardness control of electronic components for space application to high energy particles

*Monday, 12 December 2016 14:50 (30 minutes)*

The impact of high energy particles to space first and foremost connected with heavy ions are the main natural force, which determined the working capacity of electronic components that are used in the electronic equipment for spacecraft. For the last 7 years by the cooperation of the Branch of JSC "URSC"–"ISDE"and JINR FLNR have made and have been using unique in the country test facility of electronic components hardness control to heavy ion particle impact. For this period by the effort of the five testing laboratories have been tested more then 3000 electronic component part types. In the abstract would be used short summary of space ionizing radiation and their impact to electronic components, the modern approach to the preparation, carrying out tests and interpretation of tests scores, also would be detailed information about test facilities on the base of accelerator U400 and U-400M in the JINF FLRN, despite that we would like to tell you about method which are used to control and definition of beam characteristics, we have also found out the advantages and disadvantages of using testing foundation and methodology. We are based on the long experience of using heavy ion accelerators for carrying out tests, because we want to put out the disadvantages, we also would like to present the requirement of using superhigh energy faqcilities (such as NICA) for hardness control assurance of the long range electronic components item for space application. In the conclusion we would like to formulate the requirements to test facility with the use of high energy ions and we would like to make suggestions about future cooperation.

**Primary author:** Mr CHUBUNOV, Pavel (Branch of JSC URSC-ISDE)

**Presenter:** Mr CHUBUNOV, Pavel (Branch of JSC URSC-ISDE)

**Session Classification:** Radiobiology session: Continue

Contribution ID: **11** Type: **not specified**

# Testing of electronic components at accelerator complex of the FLNR JINR

*Monday, 12 December 2016 15:20 (30 minutes)*

Within six last years in FLNR JINR the project for the SEE testing facility was designed, developed and successfully commissioned. Works were initiated by need of reproduction the effects of a heavy ions component of cosmic radiation to forecast the radiation hardness of the electronic components. To date the FLNR facility dedicated for the SEE testing with heavy ions energy up to 64 MeV/nucleon is routinely used and open for the experiments. Features of diagnostic set-ups and technical parameters of created facilities are presented.

**Primary author:** Mr MITROFANOV, Semen (FLNR, JINR)

**Presenter:** Mr MITROFANOV, Semen (FLNR, JINR)

**Session Classification:** Radiobiology session: Continue

Contribution ID: **12** Type: **not specified**

# Prototype of a test bench for applied research on extracted beams of the Nuclotron accelerator complex

*Monday, 12 December 2016 15:50 (25 minutes)*

This study is devoted to the development and testing of prototypes of elements of an irradiation test bench for applied studies with extracted beams of the Nuclotron and takes into account the specific features of the accelerator complex operation. The results of the development and testing of elements of a test bench for investigating the impact of accelerated particle beams on electronics, and other targets are presented. The systems for beam monitoring and target positioning were tested on extracted argon beams in the framework of experiments on studying the radiation hardness of electronic components.

**Primary author:** Dr BALDIN, Anton (VBLHEP, JINR)

**Presenter:** Dr BALDIN, Anton (VBLHEP, JINR)

**Session Classification:** Radiobiology session: Continue

Contribution ID: **13** Type: **not specified**

# Nuclear fragmentation in metallic layers of 3D-technology electronic

A possible contribution to the upsets of on-board electronics of secondary particles –nuclear fragments originated from nuclear reactions of high energy particles, protons and ions, with materials of integrated circuits will be discussed. Space radiation has a broad spectrum of energy, a big variety of particle species with their mass variation, coming from the Sun and from Galactic and Extra-Galactic regions. Depending on the energy and mass, the particles are localized at certain altitude with respect to the Earth. The variation of the solar activity reflects variation in the Galactic Cosmic rays. The more active the Sun, the less GSRs can reach the Earth. A 3D structure electronics with a multiple layers containing transistors can be further more vulnerable to the nuclear reactions induced SEUs. Striking proton can move through a series of the heavy elements columns above the sensitive volumes in the transistor layers. This can significantly enhance the SEU possibility due to nuclear reactions.

**Primary author:** Prof. CHECHENIN, Nikolay (SINP, MSU)

**Presenter:** Prof. CHECHENIN, Nikolay (SINP, MSU)

Contribution ID: **14** Type: **not specified**

# Study of the neutron irradiation effect on SiPM based 10-channel prototype of scintillation detector module

*Tuesday, 13 December 2016 08:00 (30 minutes)*

The detectors based on solid-state photomultipliers (SiPM) are proposed for forthcoming experiments planned with relativistic heavy ions and material studies at FAIR and at NICA. We have investigated SiPM based 10-channel prototype of scintillation detector module produced at JINR by irradiating it with quasi-monoenergetic neutrons of peak energy 32 MeV and fluence ~3*10п·8 n/cm2. Secondary neutron beam was produced in the 7Li(p,n)7Be neutron generator at the NPI cyclotron (Rez,Czech Republic). It is shown that the module electronics remains operational, but the noise of SiPM increased. We applied new method to monitor changes in the breakdown voltage without measurement of SiPMs I-V characteristics. The method is based on measurement of the dependence of Vpp and Vrms voltage on the bias voltage. The proposed method can be applied for monitoring of changes in the breakdown voltage during the detector operation and does not require the usage of the additional equipment.

**Primary author:** Dr LADYGIN, Vladimir (VBLHEP, JINR)

**Presenter:** Dr LADYGIN, Vladimir (VBLHEP, JINR)

**Session Classification:** Session of ion irradiation of materials

Contribution ID: **15** Type: **not specified**

# Effect of ion velocity on the creation of point defects halos of latent tracks in alkali-halides

*Tuesday, 13 December 2016 08:30 (25 minutes)*

Parameters of the point defects halos (F-color centers) created in the nanometric vicinities of the trajectories of gold ions of 275 MeV and 2187 MeV in LiF were estimated from absorption spectroscopy experiments. Decelerations of these ions are characterized by the approximately the same electronic stopping: 24.6 and 22.9 keV/nm, respectively. In contrast to the usual concept of the velocity effect that slower ion produces larger structure changes due to the higher deposited energy density, the opposite effect seems to occur for the defect halo revealing larger radii and larger defect concentration at higher ion velocity for the same electronic energy losses. Color centers in alkali-halides appear via decay of self-trapped excitons forming due to self-trapping of valence holes. Therefore, peculiarities of spatial spreading of valence holes generated in the ionization cascades before their self-trapping results finally in a difference between the parameters of the defect halos detected in LiF crystals irradiated with different ions. But the results of application of Monte-Carlo code (TREKIS) show no significant difference in the radial distributions of valence holes in the vicinities of the ion trajectories of the slower and faster ions already at 10-50 fs after the projectile passage. Three mechanisms affecting the kinetics of valence holes, so far were not included into the current version of MC-code TREKIS, are analyzed: (i) lattice excitations during relaxation of the electronic subsystem, (ii) changes in the interatomic potential caused by intensive electronic excitations, and (iii) transient electromagnetic fields created by charge non-neutrality. The third one seems to be dominant.

**Primary author:** Dr VOLKOV, Alexander (NRC ”Kurchatov Institute”)

**Presenter:** Dr VOLKOV, Alexander (NRC ”Kurchatov Institute”)

**Session Classification:** Session of ion irradiation of materials

Contribution ID: **16** Type: **not specified**

# Nanostructure evolution in structural materials under heavy ion irradiation

*Tuesday, 13 December 2016 08:55 (25 minutes)*

Heavy ion beams are very effective instrument for the research of the radiation damage effects. Energetic ions can be used for the modification of the materials. Accelerated ions penetrate into the material from nanometers up to centimeters, depending on the ion energy and chemical composition of the material. The ion implantation results in the changes both in the material structure and its chemical composition in the irradiated region. Ion beams can be used also to understand the effects of neutron irradiation on reactor components, and interest in application of heavy ions for the imitation experiments has grown in recent years. In this report modification of nanostructured dispersion strengthened steel (structural material for advanced nuclear power plants) under heavy ion irradiation is presented. Previous studies of the effect of irradiation on the ODS Eurofer steel have showed an exchange of chemical elements between the oxide inclusions and clusters through the material matrix under irradiation. Neutron irradiation at 300℃ causes a significant change in the cluster chemical composition: vanadium goes from clusters into the matrix, and yttrium and oxygen partially leave the oxide particles and enrich clusters. In the report APT and TEM study of different ODS steels produced by mechanical alloying: ODS Eurofer, ODS13.5Cr and ODS13.5Cr0.3Ti is presented. These materials were irradiated with Fe (5.6 MeV) or Ti (4.8 MeV) ions up to 10^15 ion/cm^2 at RT and 300 ℃. In all cases, volumes for investigation were extracted from about 1 μm depth from the surface. It was found by TEM that the number density of oxide particles in all of the irradiated samples grew up and their average size went down. APT revealed essential growth of the nanoclusters number density. To sum up, irradiation of the samples may change the details of the steel nanostructure (number densities of clusters and oxides, their size distributions, as well as clusters chemical composition).

**Primary author:** Prof. ROGOZHKIN, Sergey (FSBI ”SSC RF ITEP” of NRC ”Kurchatov Institute” / NRNU MEPhI)

**Presenter:** Prof. ROGOZHKIN, Sergey (FSBI ”SSC RF ITEP” of NRC ”Kurchatov Institute” / NRNU MEPhI)

**Session Classification:** Session of ion irradiation of materials

Contribution ID: **17** Type: **not specified**

# Monitoring fluence of neutrons for investigation radiation hardness of detectors and electronics in NPI of ACSR

*Tuesday, 13 December 2016 09:20 (25 minutes)*

We will present recent result in developing of system for real time monitoring of neutrons in frame of collaboration JINR-INP. The new results concerning irradiation of SiPM will be presented. We will discuss plan in developing of the system for monitoring in real time and possibilities application of new methods in nearest future.

**Primary author:** Dr KUSHPIL, Vasily (NPI of ASRC, Czech republic)

**Presenter:** Dr KUSHPIL, Vasily (NPI of ASRC, Czech republic)

**Session Classification:** Session of ion irradiation of materials

Contribution ID: **18** Type: **not specified**

# Correction of properties and synthesis of metal-semiconductor-dielectric nanocomposite electronic structures using ion-beam technology

*Tuesday, 13 December 2016 09:45 (25 minutes)*

Not submmited

**Primary author:** Prof. FEDOTOV, Alexander (BSU, Belarus)

**Presenter:** Prof. FEDOTOV, Alexander (BSU, Belarus)

**Session Classification:** Session of ion irradiation of materials

Contribution ID: **19** Type: **not specified**

# Material studies at the LEPTA facility with positron annihilation spectroscopy

*Tuesday, 13 December 2016 10:10 (25 minutes)*

Positron annihilation spectroscopy (PAS) is a method dedicated to detection of open-volume defects such as vacancies and their clusters in structures. Nowadays, this technique is of a great interest due to the practical character of obtained results. It is successively applied in the field of material science, surface engineering and ion modification.
Recently PAS studies have been provided at the LEPTA facility at JINR. Researches using positrons emitted directly from the radioactive source and from slow positron beam are possible. In this way defects located on the depths from unit nanometers up to micrometers can be simply found. In the frame of the presentation the basics of PAS, current status of facility and directions of development will be discussed. An example of PAS application at the LEPTA in studies of Palladium, iron and copper samples irradiated with heavy ions at IC-100 cyclotron of Flerov Lab. Of Nuclear Reactions will be shown as well.

**Primary author:** Dr HORODEK, Paweł (INS of PAS, Poland / DLNP, JINR)

**Presenter:** Dr HORODEK, Paweł (INS of PAS, Poland / DLNP, JINR)

**Session Classification:** Session of ion irradiation of materials

Contribution ID: **20** Type: **not specified**

# Conical feature of damage in near surface region of TiO<sub>2</sub> and Al<sub>2</sub>O<sub>3</sub> irradiated with swift heavy ions

*Tuesday, 13 December 2016 11:00 (25 minutes)*

The study of latent track morphology in oxides irradiated with swift heavy ions is an important aspect in the ongoing quest to understand the mechanisms responsible for their creation. Latent tracks are usually assumed to be cylindrical when employing indirect methods such as RBS/C to determine damage cross sections and infer equivalent track diameters from this data. Track diameters obtained in this way are then compared with direct TEM observations (usually in plan view) for validation. In this report cross sectional TEM results obtained from near surface region of TiO2 and Al2O3 single crystals irradiated by high energy Xe and Bi ions will be presented. Conical feature of damage created in these samples is discussed since it might have tremendous implications for the correct interpretation of indirectly obtained track parameters.

**Primary author:** Mr SAIFULIN, Maxim (FLNR, JINR)

**Presenter:** Mr SAIFULIN, Maxim (FLNR, JINR)

**Session Classification:** Session of ion irradiation of materials: Continue

Contribution ID: **21** Type: **not specified**

# Ion irradiation effects in multiwalled carbon nanotubes structure

*Tuesday, 13 December 2016 11:25 (25 minutes)*

Samples of multi-walled carbon nanotubes (MWNTs) were irradiated with He ions. Scanning electron microscopy (SEM) images of the pristine and irradiatedsamples were obtained. SEM pictures showed that in the irradiated sample, the tubes are in general shorter unlike in the pristine sample. We also find from these images that average outer tube diameters change as a result of ion irradiation. The samples were also characterized using Raman spectrometry. Effects of ion irradiation were investigated through the ID/IG ratio. Modifications of the disorder mode (D-band) and the tangential mode (G-band) under different irradiation fluences were studied in detail. Asfluence increases, the MWCNTs first show disorder due to the produced defects, then healing under somewhat higher fluencies and again amorphization under still higher fluence of ion irradiation.

**Primary author:** Mr ELSEHLY, Emad (Faculty of Science, Damanhour University, Egypt / Skobeltsyn Institute of Nuclear Physics, Lomonosov Moscow State University)

**Presenter:** Mr ELSEHLY, Emad (Faculty of Science, Damanhour University, Egypt / Skobeltsyn Institute of Nuclear Physics, Lomonosov Moscow State University)

**Session Classification:** Session of ion irradiation of materials: Continue

Contribution ID: **22** Type: **not specified**

# Atomistic simulations of swift heavy ion tracks in Al<sub>2</sub>O<sub>3</sub>

*Tuesday, 13 December 2016 11:50 (25 minutes)*

The structure and formation threshold of swift heavy ion tracks in Al2O3 is studied using a combined modeling with original Monte-Carlo code TREKIS [1], describing the excitation of the electronic subsystem, and classical molecular dynamics of the lattice atoms. The advantages of developed approach are absence of free parameters and accounting for collective effects of solid state. The data obtained for Xe 167 MeV ion impact shows that the relaxation of the excess lattice energy results in the formation of a cylinder-like discontinued disordered region of about 2 nm in diameter, which is consistent with the recent transmission electron microscope observations. The estimation of SHI track formation threshold gives the value of ~7 keV/nm. The result of simulation of the x-ray diffraction pattrens of irradiated material demonstrates that Al atoms sublattice damaged stronger than the oxygen sublattice.

**Primary author:** Mr RYMZHANOV, Ruslan (FLNR, JINR)

**Presenter:** Mr RYMZHANOV, Ruslan (FLNR, JINR)

**Session Classification:** Session of ion irradiation of materials: Continue

Contribution ID: **23** Type: **not specified**

# Radiation-resistant materials and sensors for magnetic diagnostics

*Tuesday, 13 December 2016 12:15 (25 minutes)*

Here we present the results of the international collaboration of researchers for creation and testing of the radiation-resistant sensors and the magnetic measurement instrumentations based on them in the IBR-2 nuclear research reactor for the monitoring of the magnetic field under high neutron fluence environment, typical for the NICA collider, LHC at CERN, as well as for the ITER, JET, DEMO fusion reactors.
Semiconductor as well as metal materials were selected and tested in neutrons for the magnetic field sensors of the Hall type.
As it is shown, the most effective semiconductor compounds on the basis of theory predictions and experimental investigations complex are that of the III and V groups: indium antimonide (InSb) and indium arsenide (InAs). These indium-containing materials are characterized by high charge carrier mobility. A physical model of the processes that occur in these materials under the full spectrum of the reactor neutrons has been offered.
A method proposed for the parameter stabilization of the indium-containing III-V materials consist in the balancing of two competing mechanisms. It was shown that such balance could be achieved by ensuring the optimal initial charge carrier concentration. This is achieved by the doping of sensor materials with taking into account the energy spectrum of the neutron flux.
The optimal initial level of the charge carrier concentration for the InAs is n=3e18 cm^-3, it is provided via doping by tin in the process of growing. The optimal charge carrier concentration for the InSb is n=6.4e17 cm^-3. It is provided by the complex doping, which includes the main donor impurity Sn, the additional impurities Al and Cr (for creation of gettering centers of radiation induced defects), as well as rare-earth impurity Er (for binding of uncontrolled background impurities).
The radiation stability of the Hall sensors based on such semiconductor materials amounts: 99.95% at F=1e15 cm^-2 and 95% at F=1e17 cm^-2.
For even higher fluence of F≥1e19 cm-2, typical for the future DEMO reactor, radiation-resistant sensors were made based on the nano-thickness gold films (~50 nm). The main parameter –sensors sensitivity –remains unchanged up to F=2e19 cm-2
The sensors were tested in the channel #3 of IBR-2 reactor (JINR, Dubna) as well as in the channel #V13 of WWR-M reactor (PNPI, Gatchina).
Experimental investigations were carried out using online method and the remote access to the experimental data. For this purpose the special hardware-software complex was developed: sensor samples were placed in the reactor channel; control electronics were placed at a distance of 10 m from the reactor active area; the computer with the software was placed in the personnel area at a distance of 50 m from the active area.
The results obtained from the testing of the radiation-resistant semiconductor sensors were presented at FEC-2014 conference and published in Nuclear Fusion journal (2015, V.55, N8, 083006).
The results of the testing of the metal sensors were presented at the FEC-2016 conference in October 2016, published in the conference proceedings (Book of abstracts, P.473).

**Primary author:** Dr KULIKOV, Sergey (FLNP, JINR)

**Presenter:** Dr KULIKOV, Sergey (FLNP, JINR)

**Session Classification:** Session of ion irradiation of materials: Continue

Contribution ID: **24** Type: **not specified**

# Optical spectra of the near surface layers of GaAs implanted with Xe<sup>+</sup>, In<sup>+</sup> and Kr<sup>+</sup>, ellispometric and nuctear investigation

*Tuesday, 13 December 2016 12:40 (25 minutes)*

The (100) surface of SI GaAs single crystals have been doubly irradiated with Xe+ ,In+ and Kr+ ions. The ion energies were in region from 100 keV to 300 keV, and the total fluence were 3x1013 cm-2 and 3x1016 cm-2. The parameters of the ion implantation, for all ions, were chosen to provide formation of a parallel flat layer containing the constant value of atomic concentration of doped atoms in the implanted layers. The optical spectra: refraction and extinction spectra of for the all samples were determined from the spectroscopic ellipsometry (SE) measurements. The investigations were performed in the range of the wavelength from 250 nm to 900 nm at four angles of incidence of the light beam (65o, 70o, 75o and 80o). The three phase model was used for description of the investigated samples (an ambient, a parallelepiped homogeneous layer of native oxide and homogeneous substrate). The parametric model of dielectric function was used for the determination of optical spectra of irradiated samples with fluence 3x1013 cm-2 and EMA approximation was applied in the study of samples implanted with fluences 3x1016 cm-2. The thicknesses of the all implanted layers have been investigated using the nuclear methods of Rutherford backscattering spectrometry (RBS). In this study, it was assumed that the thickness of implanted layers depends only on a kind and the energy of the incident ions. It observed that the intensity of the dielectric functions near the critical points CP in the obtained spectrum is changing after radiation damage. The obtained results confirm that the measurements using the nuclear methods as well as SE technique give a consistent description of the implanted GaAs samples.

**Primary author:** Dr KULIK, Miroslaw (FLNP, JINR)

**Presenter:** Dr KULIK, Miroslaw (FLNP, JINR)

**Session Classification:** Session of ion irradiation of materials: Continue

Contribution ID: **25** Type: **not specified**

# Development and testing of space electronic components

*Monday, 12 December 2016 16:15 (25 minutes)*

Not submmited

**Primary author:** Dr TOKAREV, Vladimir (BSU, Belarus)

**Presenter:** Dr TOKAREV, Vladimir (BSU, Belarus)

**Session Classification:** Radiobiology session: Continue