Poster session
Programme Advisory Committee
for Condensed Matter Physics
(14-15 June, 2018)

Poster abstract	Remarks

1. Studies of the Wigner quasiprobability distributions

V. Abgaryan[1], A.Khvedelidze[1,2], D.Mladenov[3], I.Rogojin[1], A.Torosyan[1]

[1]*Laboratory of Information Technologies, JINR, Dubna, Russia*

[2]*Institute of Quantum Physics and Engineering Technologies, GTU, Tbilisi, Georgia*

[3]*Theoretical Physics Department, Faculty of Physics, Sofia University "St Kliment Ohridski", Sofia, Bulgaria*

akhved@jinr.ru

Nowadays, due to the quantum engineering needs, a long-standing problem of finding "quantum analogues" for the statistical distributions of classical systems became actual again. Mathematically this issue can be formulated as a problem of finding the mapping between operators on the Hilbert space of a finite-dimensional quantum system and the Wigner quasiprobability distributions [1] defined over the symplectic flag manifold [2,3]. The guideline for construction of this mapping is known as the Weyl-Stratonovich correspondence [4,5]. The Wigner quasiprobability distribution is constructed from two objects: the density matrix ρ describing a quantum state, and the so-called Stratonovich-Weyl (SW) kernel $\Delta(\Omega)$ defined over the symplectic manifold Ω.

Our studies are devoted to the construction of the SW kernel for a generic N-level quantum system. Among recently obtained results we point out the following ones:

i. It is shown that the kernel $\Delta(\Omega)$ satisfies two algebraic "master equations";
ii. An ambiguity in the solution to those "master equations" has been analyzed and the moduli space of the Wigner quasiprobability distribution was determined;
iii. The positivity of the Wigner function has been studied and the probabilistic characteristics of negativity of the Wigner functions were found.

In the present report these issues will be presented and exemplified considering the Wigner quasiprobability distributions for 2, 3 and 4-dimensional quantum systems. In particular, the results of numerical and analytical computations of the probability for the Wigner function of qubits and qutrits from Hilbert-Schmidt ensembles to take negative values will be given.

References

[1] E.P.Wigner, On the quantum correction for thermodynamic equilibrium, Phys. Rev. 40, 749-759, 1932
[2] C.Brif and A.Mann, Phase-space formulation of quantum mechanics and quantum-state reconstruction for physical systems with Lie-group symmetries, Phys.Rev. A59, 971, 1999
[3] A.Khvedelidze and V.Abgaryan, On the family of Wigner functions for N-level quantum system, arXiv: https://arxiv.org/abs/1708.05981, 2018
[4] H.Weyl, Gruppentheorie und Quantenmechanik, Hirzel-Verlag, Leipzig, 1928
[5] R.L.Stratonovich, On distributions in representation space, Soviet Physics JETP 4, 891-898, 1957.

2. Stationary and nonstationary generalized TASEP in KPZ and jamming regimes

A.E. Derbyshev[1], A.M. Povolotsky[1]

[1]*Bogoliubov Laboratory of Theoretical Physics, Joint Institute for Nuclear Research, Dubna*

derbyshev@theor.jinr.ru

The totally asymmetric simple exclusion process (TASEP) is very known exactly solvable model which belongs to Kardar-Parisi-Zhang (KPZ) universality class [1]. Despite very simple formulation, it has non trivial behavior. We investigate TASEP in discrete time with generalized updating rules (GTASEP) [2]. In addition to the usual discrete time dynamics and exclusion interaction the GTASEP has an extra parameter responsible for attractive-like interaction that affects clustering of particles. As the parameter varies in its range, the model transforms from the discrete time TASEP with parallel update to what we call the deterministic aggregation (DA). The two cases were considered. In the first case we study the stationary state correlations, the cluster size distribution and the large-time fluctuations of integrated particle current for GTASEP on a ring [3]. In the other case of infinite lattice geometry we study functional forms of the distributions in the so called "scaling limit" and describe the crossover between the KPZ and non-KPZ scaling behaviors in the cases when the KPZ universality breaks down[4].

[1] K. Kardar, G. Parisi, Y.Z. Zhang. Dynamic scaling of growing interfaces. Phys. Rev. Lett.56:889.892 (1986)
[2] A.E. Derbyshev, S.S. Poghosyan, A.M. Povolotsky and V.B. Priezzhev, The totally asymmetric exclusion process with generalized update J. Stat. Mech. (2012) P05014
[3] A E Derbyshev, A M Povolotsky, V B Priezzhev, Emergence of jams in the generalized totally asymmetric simple exclusion process.Phys Rev E Feb; 91(2): 022125 . (2015)
[4] A E Derbyshev, A M Povolotsky , Nonstationary generalized TASEP in KPZ and jamming regimes.

3. Analysis of the working ability of the planar graphene tunnel field-effect transistor in the presence of edge vacancies

A.A. Glebov[1,2], V. L. Katkov[1], V. A. Osipov[1]

[1]*Bogoliubov Laboratory of Theoretical Physics, Joint Institute for Nuclear Research, Dubna*
[2]*Moscow Institute of Physics and Technology, Dolgoprudny, Russia*

glebov.atth@gmail.com

The effect of vacancies on the robustness of zero-energy edge electronic states in zigzag-type graphene layer is studied at different concentrations and distributions of defects [1]. All calculations are performed by using the Green's function method and the tight-binding approximation. We have specified a critical distance between edge vacancies when their mutual influence becomes significant and affects markedly the density of electronic states at graphene edge. It is found that the arrangement of defects plays a crucial role in the destruction of the edge states. The results were used to describe the working ability of the planar graphene tunnel field-effect transistor (TFET) damaged by vacancies [2]. It is shown that the transistor performance depends critically on two important factors associated with the defects: the destruction of the localized electronic states and the emergence of subpeaks near the Fermi level. The supportable operation conditions of the TFET are found to be ensured at 30 percent or less of edge vacancies regardless of the type of their distribution.

[1] A.A. Glebov, V.L. Katkov, V. A. Osipov, JETP letters 104, 842 (2016).
[2] A.A. Glebov, V.L. Katkov, V. A. Osipov, EPL 118, 27003 (2017).

4. Itinerant-localized model of strongly correlated electrons: Fermi-surface reconstruction

I. Ivantsov[1,2], A. Ferraz[3], E. Kochetov[1]

[1]*Bogoliubov Laboratory of Theoretical Physics, Joint Institute for Nuclear Research, Dubna, Russia*
[2]*L.V.Kyrensky Institute of Physics, Siberian Branch of Russian Academy of Sciences, Krasnoyarsk, Russia*
[3]*International Institute of Physics - UFRN,Department of Experimental and Theoretical Physics - UFRN, Natal, Brazil*

ivantsov@theor.jinr.ru

A number of recent experiments have highlighted a remarkable transformation of a large cuprate Fermi surface into small pockets in the underdoped region signaling a breakdown of a conventional Fermi liquid theory in the PG phase [1,2]. A few phenomenological models have been recently put forward to account for this transformation [3,4]. However, none of those models have been derived microscopically nor are totally compatible with experimental data. In the present work we show that the observed Fermi-surface reconstruction can be accounted for directly within a standard microscopic *t-J* model of correlated electrons, provided strong electron correlations are properly taken into account.

[1] N. Doiron-Leyraud et al, Nature **447**, 565 (2007).
[2] Y. He et.al., Science **344**, 608 (2014).
[3] Y. Qi and S. Sachdev, Phys. Rev. B **81**, 115129 (2010).
[4] N. Harrison and S.E. Sebastian, Phys. Rev. Lett. **106**, 226402 (2011).

5. The heat capacity of dimerized antiferromagnetic spin chains with S=1/2 at low temperatures

V.L. Katkov

Bogoliubov Laboratory of Theoretical Physics, Joint Institute for Nuclear Research, Dubna

katkov@theor.jinr.ru

A spin linear chain with antiferromagnetic interaction of nearest neighbors is considered. The interaction constants of each spin with the right and left neighbors are different. Within the framework of the Bulaevskii's theory, the temperature dependence of magnetic heat capacity is calculated for different parameters of alternation. It is shown that at low temperature the behavior of the heat capacity has two regimes. In the former the temperature is less than the half of gap, while $C = A\ T^{-1} \exp(-D/k_BT)$, in the latter the temperature exceeds the half of gap. In this case C is approximately proportional to T. The results clearly show that phenomenological law $C=A\ T \exp(-D/k_BT)$ found early in experiments [1-3] for this system could not be consequence of the weak dimerisation.

[1] S. Majumdar, V. Hardy, M. R. Lees, D. M. Paul, H. Rousseliere, and D. Grebille, Phys. Rev. B 69, 024405 (2004).
[2] S. Sahling, G. Remenyi, J. E. Lorenzo, P. Monceau, V. L. Katkov, and V. A. Osipov, Phys. Rev. B 94, 144107 (2016).
[3] S. Sahling, J. E. Lorenzo, and V. L. Katkov, submitted to Journal of Low Temperature Physics.

6. Josephson junction with two superconducting current components

K.V. Kulikov[1,2], R. Davood [3] , E. P. Nakhmedov [4,5] , and Yu. M. Shukrinov [1,2]

[1]*Bogoliubov Laboratory of Theoretical Physics, Joint Institute for Nuclear Research, Dubna*
[2]*Dubna State University, Dubna, Russia*
[3]*University of Cairo, Cairo, Egypt*
[4]*Baku Branch, Moscow State University, Baku, Azerbaijan*
[5]*Institute of Physics, National Academy of Sciences of Azerbaijan, Baku, AZ1143 Azerbaijan*

kulikov@theor.jinr.ru

The properties of a Josephson junction with the 2π- and 4π-periodic superconducting current component have been analyzed. It exhibits the 4π periodicity of the phase difference in the range of low voltages for the Majorana current amplitude much smaller than the Josephson current which makes it possible to observe Josephson current oscillations with a fractional period for small dissipation $\beta < 1$ in the hysteresis region. The effect of 4π-periodic Majorana current component is also manifested itself of the current-voltage characteristic as an additional sequence of the Shapiro steps in the staircase structure. We have determined the interval of external electromagnetic radiation amplitudes, in which the manifestation of the fractional Josephson effect on the current-voltage characteristic is the most significant.

7. Modelling of LC-shunted intrinsic Josephson junctions in high-T_c superconductors

Yu.M. Shukrinov[1,2] , I.R. Rahmonov[1,3] , K.V. Kulikov[1,2] , A.E. Botha[4] , A. Plecenik[5] , P. Seidel[6] , W. Nawrocki[7]

[1]*Bogoliubov Laboratory of Theoretical Physics, Joint Institute for Nuclear Research, Dubna*
[2]*Dubna State University, Dubna, Russia*
[3]*Umarov Physical Technical Institute, Dushanbe, Tajikistan*
[4]*Department of Physics, University of South Africa, Florida, South Africa*
[5]*Department of Experimental Physics, Comenius University, Bratislava, Slovakia*
[6]*Friedrich-Schiller-Universitat, Institut fur Festkorperphysik, Jena, Germany*
[7]*Poznan University of Technology, Poznan, Poland*

kulikov@theor.jinr.ru

Resonance phenomena in a model of intrinsic Josephson junctions shunted by LC-elements (L-inductance, C-capacitance) are studied. The phase dynamics and IV-characteristics are investigated in detail when the Josephson frequency approaches the frequency of the resonance circuit. A realization of parametric resonance through the excitation of a longitudinal plasma wave, within the bias current interval corresponding to the resonance circuit branch, is demonstrated. It is found that the temporal dependence of the total voltage of the stack, and the voltage measured across the shunt capacitor, reflect the charging of superconducting layers, a phenomenon which might be useful as a means of detecting such charging experimentally. Thus, based on the voltage dynamics, a novel method for the determination of charging in the superconducting layers of coupled Josephson junctions is proposed. A demonstration and discussion of the influence of external electromagnetic radiation on the IV-characteristics and charge-time dependence is given. Over certain parameter ranges the radiation causes an interesting new type of temporal splitting in the charge-time oscillations within the superconducting layers.

8. Shapiro step at nonequilibrium condition

K.V. Kulikov[1,2], Yu.M. Shukrinov [1,2], M. Nashaat[1,3], A. Irie[4]

[1]*Bogoliubov Laboratory of Theoretical Physics, Joint Institute for Nuclear Research, Dubna*
[2]*Dubna State University, Dubna, Russia*
[3]*Department of Physics, Cairo University, Cairo, Egypt*
[4]*Utsunomiya University, Utsunomiya, Japan*

kulikov@theor.jinr.ru

Influence of the charge imbalance effect on the system of intrinsic Josephson junctions of high temperature superconductors under external electromagnetic radiation are investigated. We demonstrate that the charge imbalance is responsible for a slope in the Shapiro step in the IV-characteristic. The nonperiodic boundary conditions shift the Shapiro step from the canonical position which determined by a frequency of external radiation. We also demonstrate how the system parameters effect on the shift of Shapiro step.

9. TEM and SEM studies of colloid silver nanoparticles

O.V. Kristavchuk[1,2], Lizunov N.E.[1], A.S. Sohatsky[1,2], A.N. Nechaev[1,2], P. Yu. Apel[1,2]

[1]*Flerov Laboratory of Nuclear Reactions, Joint Institute for Nuclear Research, Dubna, Russia*
[2]*Dubna State University, Dubna, Russia*

artoshina@jinr.ru

Silver nanoparticles (NP) are used in electronic, optical and sensory devices, including sensors based on the effect of surface-enhanced Raman scattering (SERS). Among all the variety of methods for the NP production, a very simple, "pure" way is distinguished, in which nanoparticles are formed by sputtering silver from the surface of silver electrodes into the volume of distilled water during the process of a high-voltage discharge [1]. The result is a stable colloidal solution free of surfactants, which can be used to modify track-etched membranes (TM) by silver nanoparticles. This is a promising method that allows obtaining a flow-through SERS-active substrate with high sensitivity to different compounds, including important biological molecules.

A scanning (SEM, Hitachi SU8020, FLNR JINR) and transmission (TEM, JEOL JEM 2100LaB6, CHRTEM NMMU, South Africa) electron microscopy were applied to study silver nanoparticles from the solution. To do this, the meshes for the TEM were dip-coated in a colloidal solution for several days, dried, and examined first by SEM, and then by TEM. The presence of both a nanopowder of cubic silver and single-crystal plates with a hexagonal close-packed lattice was detected on the X-ray patterns, and a presence of a shell of unknown origin around the nanoparticle was detected.

The study of nanostructures on the TM surface was carried out by SEM (Hitachi SU8020, FLNR JINR). For this purpose, the membranes were kept in solution for 2 days, dried and analyzed. On the basis of electron micrographs, the shape, degree of agglomeration of the nanoparticles, their distribution over the TM surface were evaluated, and a histogram of the silver particle size distribution was constructed.

[1] N.N. Ostroukhov, A.Yu. Tyanginskii, V.V. Sleptsov, M.V. Tserulev. Inorganic Materials: Applied Research, 2014, Vol. 5, No. 3, pp. 284–288.

10. Devil's staircase and chaos in Josephson junctions

S.Yu. Medvedeva[1], Yu.M. Shukrinov[2,3]

[1]*Moscow Institute of Physics and Technology (State University), Moscow, Russia*
[2]*Joint institute for nuclear research, Dubna, Moscow Region, Russia*
[3]*Dubna State University, Dubna, Moscow region, Russia*

medvedeva_sveta@list.ru

Devil's staircase is an interesting phenomena observed in various systems, such as Josephsons junctions [1], fractional quantum Hall effect [2], and even in the ocean-atmosphere systems [3]. Results on the study of the devil's staiscase as in single Josephson junction and in the stack of coupled Josephson junctions are presented. We have used capacitively coupled Josephson junctions model [4] to calculate voltage-current characteristics. We demonstrate the devil's staircases at different values of the model parameters [5]. The influence of coupling parameter on chaotic regions and subharmonic structure in IV-characteristics is studied. Results of the detailed study of the coupling between junctions on IV-characteristics at the fixed values of model parameters, particularly, dissipation parameter β=0.2, 0.3, 0.4 frequency of external radiation Ω=0.5 and amplitude A=0.8 are presented.

[1] Yu. M. Shukrinov, A. E. Botha, S. Yu. Medvedeva, M. R. Kolahchi, and A. Irie. Chaos: An Interdisciplinary Journal of Nonlinear Science, **24**, 033115 (2014).
[2] R. B. Laughlin et al., Phys. Rev. B, **32**, 1311 (1985).
[3] F.-F. Jin, J. D. Neelin, M. Ghil, Science, **264**, 70–72 (1994).
[4] Yu.M. Shukrinov, F. Mahfouzi, P. Seidel, Physica C, **62,** 449 (2006).
[5] Yu. M. Shukrinov, S. Yu. Medvedeva, A. E. Botha, M. R. Kolahchi, A. Irie. Phys. Rev. B, **88**, 214515 (2013).

11. Charge Dynamics in strongly-correlated electronic Systems

D. T. Nguyen, N. M. Plakida

nguen@theor.jinr.ru

BLTP, Joint Institute for Nuclear Research, Dubna, Russia

We consider the dynamic charge susceptibility and charge density waves in strongly-correlated electronic systems within the two-dimensional t-J-V model. Using the equation of motion method for the relaxation functions in terms of the Hubbard operators we calculate the static susceptibility and the spectrum of charge fluctuations as functions of doped hole concentrations and temperature. Charge density waves emerges for a sufficiently strong intersite Coulomb interaction.

12. Effect of inductive and capacitive coupling on the current–voltage characteristic and electromagnetic radiation from a of Josephson junctions stack

I.R. Rahmonov[1,2], Yu. M. Shukrinov[1,3], P. Kh. Atanasova[4], E. V. Zemlyanaya[3,5], M. V. Bashashin[3,5]

[1]*Bogoliubov Laboratory of Theoretical Physics, Joint Institute for Nuclear Research, Dubna*
[2]*Umarov Physical-Technical Institute, Dushanbe, Tajikistan*
[3]*Dubna State University, Dubna, Russia*
[4]*Paisii Hilendarski University of Plovdiv, Plovdiv, Bulgaria*
[5]*Laboratory of Information Technologies, Joint Institute for Nuclear Research, Dubna, Russia*

rahmonov@theor.jinr.ru

We have studied the current–voltage characteristic of a stack of long Josephson junctions taking into account the inductive and capacitive coupling. The dependence of the average time derivative of the phase difference on the bias current and spatiotemporal dependences of the phase difference and magnetic field in each junction are considered. The possibility of branching of the current–voltage characteristic in the region of zero field step, which is associated with different numbers of fluxons in separate Josephson junctions, is demonstrated. The current–voltage characteristic of the system of Josephson junctions is compared with the case of a single junction, and it is shown that the observed branching is due to coupling between the junctions. The intensity of electromagnetic radiation associated with motion of fluxons is calculated, and the effect of coupling between junctions on the radiation power is analyzed.

13. Novel collective excitations in the stack of long Josephson junctions

I.R. Rahmonov[1,2], Yu.M. Shukrinov[1,3], A. Irie[4]

[1]*Bogoliubov Laboratory of Theoretical Physics, Joint Institute for Nuclear Research, Dubna*
[2]*Umarov Physical-Technical Institute, Dushanbe, Tajikistan*
[3]*Dubna State University, Dubna, Russia*
[4]*Utsunomiya University, Utsunomiya, Japan*

rahmonov@theor.jinr.ru

We investigate the phase dynamics of the stack of long Josephson junctions (JJ) with inductive and capacitive couplings. The current–voltage characteristics (CVC), the spatiotemporal dependence of electric charge in superconducting layers and magnetic field in the JJs was calculated. We have shown an appearance of longitudinal plasma wave (LPW) and realization of parametric resonance [1, 2]. The coexistence of a fluxon state and LPW is predicted. Charge distribution along the coordinate x is nonuniform in all JJ of the system due to the excitation of the fluxon (antifluxon) states. This conclusion is confirmed by the distribution of the magnetic field in Josephson junctions along the stack and x coordinate. This fact can be interpreted as the possibility an appearance of a new collective excitation that is a composite state of the LPW and vortex magnetic field [3]. Also, the coexistence of the charge travelling wave [4] and fluxons has been found.

[1] I. R. Rahmonov, Yu. M. Shukrinov and A. Irie, JETP Lett. 99, 632-639 (2014).
[2] Yu. M. Shukrinov, F. Mahfouzi, Phys. Rev. Lett. 98, 157001 (2007).
[3] M. Tachiki and M. Machida, Physica C 341-348, 1493 (2000).
[4] Yu. M. Shukrinov and M. Hamdipour, JETP Lett. 95, 307-313 (2012).

14. Phase dynamics of SFS structure and magnetization reversal

I.R. Rahmonov[1,2], Yu.M. Shukrinov[1,3], A. Irie[4]

[1]*Bogoliubov Laboratory of Theoretical Physics, Joint Institute for Nuclear Research, Dubna*
[2]*Umarov Physical-Technical Institute, Dushanbe, Tajikistan*
[3]*Dubna State University, Dubna, Russia*
[4]*Utsunomiya University, Utsunomiya, Japan*

rahmonov@theor.jinr.ru

In the Superconductor-Ferromagnetic-Superconductor structure (SFS) Spin-Orbit coupling leads to the direct coupling of the magnetic moment and Josephson current[1]. The possibility of the magnetic moment control by the Josephson current (or vice versa) attracts much interest of researchers [1-5]. We have shown the results of the numerical simulation of the dynamics of the magnetic moment in SFS structure in the framework of the Phi-0 junction in the presence of current pulse. The full reversal of magnetization is demonstrated under the influence of the current pulse.

[1] A. Buzdin, Phys. Rev. Lett. 101, 107005 (2008).
[2] A. I. Buzdin, Rev. Mod. Phys. 77, 935 (2005).
[3] F. S. Bergeret, A. F. Volkov, and K. B. Efetov, Rev. Mod. Phys. 77, 1321 (2005).
[4] A. A. Golubov, M. Y. Kupriyanov, and E. Ilichev, Rev. Mod. Phys. 76, 411 (2004).
[5] F. Konschelle, A. Buzdin, Phys. Rev. Lett. 102 , 017001(2009).

15. Peculiarities of the phase dynamics of a ring system of parallel Josephson junctions

K.M. Rodin[1,2], I.R. Rahmonov[1,2], Yu. M. Shukrinov[1,2]

[1]*Bogoliubov Laboratory of Theoretical Physics, Joint Institute for Nuclear Research, Dubna*
[2]*Dubna State University, Dubna, Russia*

rayquaza@list.ru

The ring system of parallel Josephson junctions attracts much attention researchers due to the rich nonlinear properties [1-3]. In such systems the main excitations are the kink fluxons and plasma oscillations [2]. We investigate the phase dynamics of the ring system of parallel Josephson junctions. IV -characteristics and time dependences of voltage and magnetic field for different values of the bias current are calculated. The branching structure of IV-characteristic is simulated and analyzed. We have shown the branching of the zero field steps.

[1] J. Pfeiffer, A.A. Abdumalikov, Jr.M. Schuster, and A. V. Ustinov, Phys. Rev. B 77, 024511 (2008).
[2] A. V. Ustinov, M. Cirillo, B. A. Malomed, Phys. Rev. B 47, 8357 (1993).
[3] M. Lucci, D. Badoni, V. Merlo, I. Ottaviani, G. Salina, M. Cirillo, A. V. Ustinov, and D. Winkler, Phys. Rev. Lett. 115, 107002 (2015).

16. Recrystallization role in ion track formation in dielectrics

R.A. Rymzhanov[1], N.A. Medvedev[2,3], J.H. O'Connell[4], A. Janse van Vuuren[4], V.A. Skuratov[1,5,6] , A.E. Volkov[1,7,8]

[1]*Joint Institute for Nuclear Research, Moscow Region, Russia*
[2]*Institute of Physics, Czech Academy of Sciences, Prague, Czech Republic*
[3]*Institute of Plasma Physics, Czech Academy of Sciences, Prague, Czech Republic*
[4]*Nelson Mandela Metropolitan University, Port Elizabeth, South Africa*
[5]*National Research Nuclear University MEPhI, Moscow, Russia*
[6]*Dubna State University, Dubna, Russia*
[7]*National Research Center 'Kurchatov Institute', Moscow, Russia*
[8]*Lebedev Physical Institute of the Russian Academy of Sciences, Moscow, Russia*

rymzhanov@jinr.ru

We compared the structural response of three oxide crystals - MgO, Al_2O_3 and $Y_3Al_5O_{12}$ (YAG) to swift 167 MeV xenon ion irradiation using a combined approach based on original Monte Carlo code TREKIS describing excitation of the electronic subsystem and energy and momentum transfer into the lattice, and classical molecular dynamics (MD) simulations of subsequent lattice relaxation. Results of simulations were compared with the transmission electron microscopy (TEM) data. It was found that despite the comparable energy deposition, Xe ions produce quite different damage in these materials. MD modeling revealed that the size and structure of SHI track regions largely depend on the possibility of recrystallization of the initially disordered hot area.

The highest level of recrystallization in MgO almost completely recovers transient damage. There are only a few point defects left in MgO and no clear SHI track is formed which is in agreement with TEM observation. Recrystallization in Al_2O_3 is rather slow, producing damaged crystalline discontinuous tracks of ~2 nm during cooling. This also agrees well with experimental high resolution TEM images. YAG demonstrated almost no recovery of the initial disorder, forming continuous amorphous tracks with a cylindrical shape and the diameter of ~5.1 nm. Experimentally observed tracks are also amorphous, but have larger diameters of ~ 6.5 nm.

17. Enhancement of thermoelectric figure of merit in zigzag graphene nanoribbons with periodic edge vacancies

D.V. Kolesnikov, O.G. Sadykova, V.A. Osipov

Bogoliubov Laboratory of Theoretical Physics, Joint Institute for Nuclear Research, Dubna

issaeva@theor.jinr.ru

The increasing development of new experimental techniques, which allow for the controlled growth of graphene nanostructures and manipulation of the graphene edges at the atomic level has opened up new possibilities for promising applications Among them is the design of new high-efficiency thermoelectric materials and devices. In order to achieve high thermoelectric efficiency of graphene, one needs to significantly increase the Seebeck coefficient and simultaneously reduce the phonon thermal conductance. Many attempts were made to realize this program in various graphene-based structures including nanostructuring in periodic graphene patterns, which results in the bandgap opening [1-3] and incorporation and dimensional tuning of nanopores [4,5].

The influence of periodic edge vacancies and antidot arrays on the thermoelectric properties of zigzag graphene nanoribbons (ZGNRs) are investigated. Using Green's function method, the tight-binding approximation for the electron Hamiltonian and the 4th nearest neighbor approximation for the phonon dynamical matrix, we calculate the Seebeck coefficient and the thermoelectric figure of merit. It is found that, at a certain periodic arrangement of vacancies on both edges of zigzag nanoribbon, a finite band gap opens and almost twofold

degenerate energy levels appear. As a result, a marked increase in the Seebeck coefficient takes place. It is shown that an additional enhancement of the thermoelectric figure of merit can be achieved by a combination of periodic edge defects with an antidot array [6].

[1] Y. Yan et al., *Phys. Lett. A* 376, 2425 (2012).
[2] H. Sevincli et al., *Sci. Rep.* 3, 1228 (2013).
[3] L. A. Algharagholy et al., *Nanotechnol.* 26, 475401 (2015).
[4] Md. S. Hossain et al., *Nature: Sci. Rep.* 5, 11297 (2015).
[5] H. Sadeghi, S. Sangtarash and C. J. Lambert, *Sci. Rep.* 5, 9514 (2015).
[6] D.V. Kolesnikov, O.G. Sadykova, V.A. Osipov. *Int. Journal of Modern Physics B* Vol.31, No. 15 (2017) 1750124 (10 pages)

18. Verification of the swift heavy ion irradiation velocity effect in $Y_3Fe_5O_{12}$ and $Y_3Al_5O_{12}$ single crystals by TEM observations of latent tracks

M.M. Saifulin[1,2], J.H. O'Connell[3], A. Janse van Vuuren[3], V.A. Skuratov[1,2,4], N.S. Kirilkin[1], M.V. Zdorovets[5,6]

[1]*Joint Institute for Nuclear Research, Dubna, Russia*
[2]*National Research Nuclear University MEPhI, Moscow, Russia*
[3]*Nelson Mandela Metropolitan University, Port Elizabeth, South Africa*
[4]*Dubna State University, Dubna, Russia*
[5]*Institute of Nuclear Physics, Astana, Kazakhstan*
[6]*Ural Federal University, Yekaterinburg, Russia*

saifulin@jinr.ru

The characterization of swift heavy ion induced latent track morphology in various insulators plays an important role for correct understanding of material damage process due to high density electronic excitations. Nowadays a number of direct and indirect methods are presented to evaluate latent track parameters (diameter and threshold of formation) as a function of electronic energy losses, ion velocity and irradiation temperature. However, there is some discrepancy between the results of direct and indirect measurements, related to the lack of a clear representation of the morphology of latent tracks in various materials. In this work, the attention is drawn to verification of the so called "velocity effect" in $Y_3Fe_5O_{12}$ and $Y_3Al_5O_{12}$ single crystals (YIG and YAG) for which the most part of the data on latent track size have been obtained using indirect methods. Bulk YIG and YAG single crystals have been irradiated with 23 MeV/u Kr and 20.5 MeV/u Xe ions at MC400 cyclotron, and 1.2 MeV/u Kr and Xe ions at IC100 cyclotron in FLNR JINR, Dubna. Aluminum foils of different thicknesses have been used to vary the velocity of Kr and Xe ions at high energy beams. Morphology of the latent tracks induced in irradiated YIG and YAG crystals have been studied by HR-STEM method. Plain-view samples for HR-STEM observations have been prepared by focused ion beam (FIB) method.

The results of direct HR STEM observation of latent track morphology after Kr and Xe ion irradiation in low and high velocity regimes showed that there is a difference in the latent tracks size for low and high velocity irradiated YIG and YAG, indicating on the velocity effect. However, the differences are much smaller than those obtained by indirect methods. Possible reasons of inconsistency in track sizes from direct and indirect measurements are discussed.