Institute of High Current Electronics SB RAS
Tomsk Scientific Center SB RAS
National Research Tomsk Polytechnic University

6th International Congress on Energy Fluxes and Radiation Effects (EFRE 2018)

Abstracts

September 16–22, 2018

Tomsk, Russia

Tomsk

Publishing House of IAO SB RAS

2018

Conferences

20th International Symposium on High-Current Electronics
14th International Conference on Modification of Materials with Particle Beams and Plasma Flows
18th International Conference on Radiation Physics and Chemistry of Condensed Matter
3rd International Conference on New Materials and High Technologies

6th International Congress on Energy Fluxes and Radiation Effects (EFRE 2018): Abstracts. — Tomsk: Publishing House of IAO SB RAS, 2018. — 675 pp.

Edited by: Nikolay Ratakhin, Nikolai Koval, Alexey Yakovlev, Alexey Markov.

This book comprises the abstracts of the reports (presentations) for the oral and poster sessions of VI International Congress on Energy Fluxes and Radiation Effects (EFRE 2018). The Congress will combine four International Conferences regularly hosted in Tomsk: International Symposium on High-Current Electronics, International Conference on Modification of Materials with Particle Beams and Plasma Flows, International Conference on Radiation Physics and Chemistry of Condensed Matter, International Conference on New Materials and High Technologies. It will be a good platform for researchers to discuss a wide range of scientific, engineering, and technical problems in the fields of pulsed power technologies; ion and electron beams; high power microwaves; plasma and particle beam sources; modification of material properties; pulsed power applications in chemistry, biology, and medicine; physical and chemical nonlinear processes excited in inorganic dielectrics by particle and photon beams; physical principles of radiation-related and additive technologies; self-propagating high-temperature synthesis; and combustion waves in heterogeneous systems.

The Congress was financially supported by FASO Russia and RFBR grants: 18-02-20100 (SHCE), 18-08-20066 (CMM), 18-03-20069 (NMHT), 18-38-10031 (School).

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VI International Congress on Energy Fluxes and Radiation Effects
EFRE 2018
Tomsk, September 16–22, 2018

Dear friends and colleagues,

Welcome to the International Congress on Energy Fluxes and Radiation Effects hosted in Tomsk!

Being a large scientific event, the Congress combines the 20th International Symposium on High Current Electronics, 14th International Conference on Modification of Materials with Particle Beams and Plasma Flows, 18th International Conference on Radiation Physics and Chemistry of Condensed Matter, and 3rd International Conference on New Materials and High Technologies.

These fields of fundamental and applied research show more and more progress on the way to more advanced equipment and innovative technologies for industry, power engineering, and medicine, and the Congress is a good platform for interdisciplinary collaboration of theorists, experimenters, engineers, and technologists.

At the Congress, You can hear plenary reports on major issues from leading scientists at joint meetings and can discuss invited, oral, and poster reports on special issues at individual sessions in the four fields.

We hope that You will enjoy close communication in formal and informal surroundings and that this communication will favor current and new collaborations not only for "old-timers" but also for young scientists, postgraduates, and students.

We wish all Congress participants an excellent presentation of R&D results to colleagues and to those who can promote the results in engineering, industry, and technology for the benefit of our society.

Let the busy and rest time at the Congress be fruitful, and the cooperation be stable, mutually advantageous, and lasting for many years.

Success and Good Luck!

Congress Chairman Academician Nikolay Ratakhin
September, 2018

Plenary Session

PRECISE DIES SURFACE TREATMENT WITH CHARGED PARTICLE BEAM

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Three cases precise dies surface treatment with the charged particle beam are reported here. (1) is the intraocular lens mother dies that are made with the electro less nickel plating on the steel substrate. In the case, Ar-ion irradiation was applied. (2) is T-dies for advanced optical films injection machines, and the dies are made with STAVAX ®. The treatment was done with Nitride Plasma Treatment (PINK ®). (3) is to treat the copper system dies – especially pseudo-spinodal hardening alloy dies with Carbon atoms irradiation.

Fig. 1(a)

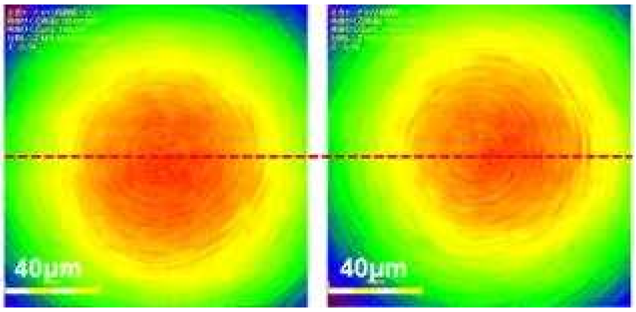

Fig. 1(b)

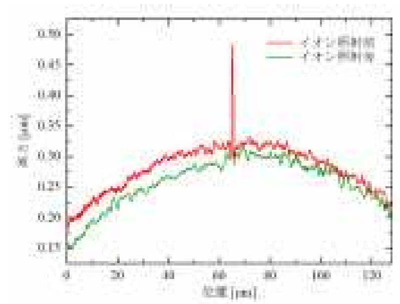

Fig. 1(c)

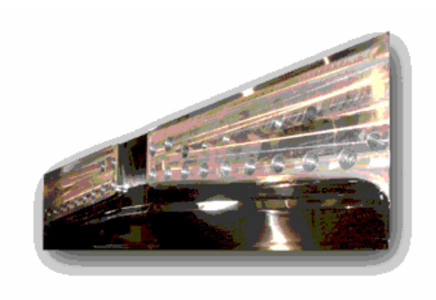

Fig. 2(a)

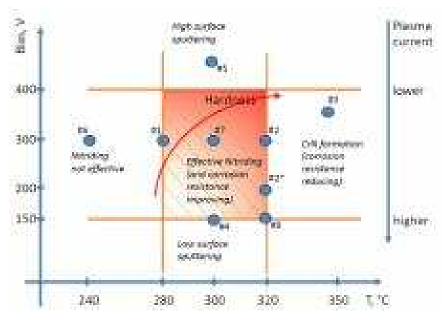

Fig. 2(b)

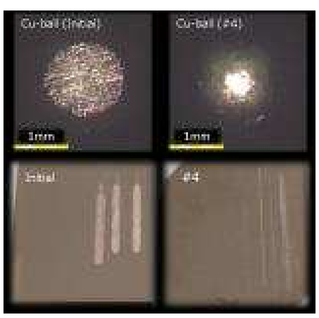

Fig. 3(a)

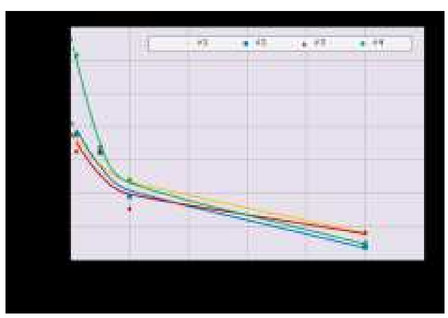

Fig. 3(b)

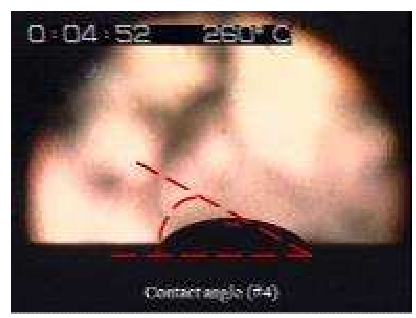

Fig. 3(c)

Fig.1 (a, b, c) show the intraocular lens mother dies before/after Ar ion irradiation [1]. Fig. 2 (a, b) show T-die and the criteria function of treated temperature and the bias voltage. [2] Fig. 3 (a, b, c) show the effect of C-ions irradiation on the hardness change and on the tribology changes [3] . In case of (1) - the intraocular lens mother dies, Ar-Ion gun irradiation parameters were 4kV, 70mA and 32sccm. The tooled protrusion of the die center was eliminated. In case of (2) T-dies, the variable parameter range was 150-450 bias voltage, and the die temperature varied 240°C-350°C with adjusting the discharge current. Keeping Ra 0.04μm and HV700(10grf) surface, the wetting angle was increased from 35°(initial) to 54° against COP resign at 295°in N 2 furnace.

In case of (3) - pseudo-spinodal hardening alloy dies, C-ion originated CH 4 was applied in the condition of $4x10^{-5}$ Pa, 30kV and beam current $2mA/cm^2$. Dose was varied from 1x10 16 to $5x10^{17}$. HV (1grf) was increased 420 to 490 keeping Ra decreasing 0.003 to 0.0018μm. Wetting angle showed from 29° to 39° with COP resign in 260°C -N^2 furnace. Ra decreasing of the intraocular lens mother dies surface is essential to reduce the irregular reflection for the cataract patients. The surface tribology modification of T-Dies is inevitable for the dies maintenance to film the high valued optical resign. To increase the hardness, keeping the good thermal conductivity, is expected further application increasing of Copper System dies.

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CURRNT STATE OF DEVELOPMENT OF ION SOURCES FOR HARDENING OF MASHINE PARTS AND TOOLS AND ALLOYING AND SEMICONDUCTORS

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Modern Ion Sources for Semiconductor Implantation including flat panel display are reviewed. Development of a Freeman and Bernas-Whit prolonger lifetime ion sources are discussed [1]. Development of a small anode ion sources reviewed [2, 3, 4]. Microwave ion sources for Ion implantation are reviewed [5]. Negative ion source for high energy tandem implanter is discussed [6]. Ion source for large and very large ribbon ion beam system for flat panel display implantation is described [7] A space charge compensation of ion beam and instability damping is discussed [8, 9, 10]. Hall drift anode layer plasma accelerators are reviewed [11]. Vacuum arc sources are discussed [12].

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ACCELERATOR DRIVEN HIGH ENERGY DENSITY SCIENCE[1]

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High intensity particle accelerators like FAIR at GSI Darmstadt and the proposed HIAF facility in China are a new tools to induce High Energy Density states in matter. We will address a topic that has until now not been investigated in detail but is paramount to the operation of high intensity accelerators as drivers for inertial fusion or high energy density physics experiments. This is the investigation of activation processes of structural components of heavy ion accelerators due to beam loss during operation. This is a crucial issue to optimize the choice of construction materials and maintenance procedures. Significant optimization of the operation schedule can be achieved if the accumulated residual activity is properly controlled and predicted. Radiation may cause changes of the functional properties of the construction materials, which possibly leads to shortening of their lifetime. Replacing of the activated accelerator components is affected by dose-rate restrictions for the "hands-on" maintenance. Handling and final disposal of the accelerator parts after several years of usage is also an important issue directly related to the activation.

Physics (HEDP) with intense heavy ion beams as a tool to induce extreme states of matter. The development of this field connects intimately to the advances in accelerator physics and technology. At Xi'An Jiaotong University we are starting a group that will build a low energy, high current ion beam facility for basic beam plasma interaction physics and will make use of existing machines at the Gesellschaft für Schwerionenforschung (GSI-Darmstadt), the Institute of Theoretical and Experimental Physics in Moscow (ITEP-Moscow), and the Institute of Modern Physics (IMP-Lanzhou).

[1] China NSFC grants: U1532263, 11505248, 11375034, 11205225, 11275241, and 11275238

SANDIA-HIGH CURRENT ELECTRONIC INSTITUTE (HCEI) COLLABORATION IN FAST LTD DEVELOPMENT

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Following the impressive operational success of the first slow (~1 microsecond) LTD in Gramat, France, that was invented, designed and built by the team at HCEI headed by Boris Kovalchuk [1, 2], Dillon McDaniel of Sandia asked the inventors if they could apply this technology for the production of fast ~100 ns pulses. The inventors accepted the challenge, and a number of communications [3] were exchanged between Sandia and HCEI on how the fast LTDs could be used for this research. The first published theoretical analytical study of such fast LTDs was presented in the 1999 Pulsed Power Conference in Monterey, California by M. G. Mazarakis et al., [4]. This paper attracted a lot of interest in the pulsed power community, resulting in a large number of requests for copies. Following that, a strong collaboration started between Sandia and HCEI that culminated in the production of 10 of the largest to-date 1 MA, 1 GW fast LTD cavities which compose now the MYKONOS voltage adders at Sandia.The different stages of the fast LTD development through the years and the up-to-date accomplishments will be presented. Although this technology has mushroomed around the globe, this paper will concentrate solely in the Sandia-HCEI collaboration.

FEATURES OF THE COLD-CATHODE THYRATRON OPERATION IN THE LINEAR ACCELERATOR LIU-2[1]

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Performance of X-ray radiography tasks implies detection of fast processes with a high spatial resolution at large optical thickness of an object of investigation [1, 2]. A choice has been made in favor of a linear induction accelerator with magnetic cores (LIU-20), an energy of 20 MeV, and a current of 2 kA. The design of this accelerator is developed by the Budker Institute of Nuclear Physics under the assignment of the Zababakhin All-Russia Research Institute of Technical Physics. At the first stage of project implementation, an injector was designed, manufactured, put into operation, and used as an independent X-ray unit LIU-2 [3].

The LIU-2 consists of the following parts: the electron-optical system, the beam diagnostic system, the pulse high-voltage supply system, the target assembly and the control system. The pulse high-voltage supply system has been designed for producing two rectangular pulses of the accelerating voltage with an adjustable time interval between them. This system consists of a pulse high-voltage transformer of the inductor type, a cable system connecting the pulse high-voltage power sources (modulators) with the sections of the pulse high-voltage transformer, 48 modulators, two charging devices, and a cable system for connecting the charging devices to the modulators.

The principle of modulator operation based on successive switching of two forming lines to the inductor [4]. Time interval between the switching is (2 - 30) μs. As a result, two successive voltage pulses with amplitude 21 kV are formed. Switching devices in modulators have to satisfy to special requirements. Each of 96 switches must sustain high voltage up to 45 kV, commutate current up to 10 kA and operate with the stability not worse than ±4 ns. Such the requirements can be fulfilled by the cold-cathode thyratrons (pseudospark switches), that are produced commercially by the Pulsed Technology Ltd. (Ryazan, Russia, http://www.pulsetech.ru/index.htm), namely TPI1-10k/50 and theirs modifications [5-8]. These thyratrons are capable to operate with an anode voltage of up to 50 kV and maximum current of 10 kA.

Current report deals with the features of cold-cathode thyratron operation in the scheme of LIU-2 modulators.

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[1] This work was supported by the Integrated Program for Basic Research of SB RAS "Interdisciplinary integration studies" on 2018-2020., the project "Study of low-pressure high-current pulsed discharges and the development of the switch prototype for the parallel switching in accelerator LIU-20"

POWER SPECTRA IN INTERACTION OF CHARGED PARTICLE BEAMS WITH GAS AND PLASMA[1]

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Charged particles beams are divided in two groups – external beams of electrons and ions and internal created by internal processes in plasma due to collective or collisional processes like runaway electrons. External energy beams could be produced by x-rays, nuclear fission reactions, laser acceleration of electrons or ions, stopping power of charged particles or other sources. Almost in all cases there arise Universal Inverse Power Spectra (UIPS) which could be with positive or negative fluxes in energy or wave numbers spaces. There is the one exclusion of zero flux (j=0) in energy space which corresponds to Equilibrium Plasma Maxwellian Distribution, which has no power tail. There are many examples of UIPS

- Space (Cosmic) Rays
- Kolmogorov’s Turbulence
- Stopping Power fast charged particles (electrons, ions in a gas or plasma) ICF plasma
- Vibrational Anharmonic Molecular Ladder Treanor Distribution
- Nuclear Excited Fission Plasma
- Electron Beam Plasma
- Quantum Distribution in the Equilibrium Plasma ?

The example of UIPS for Electron Distributions under High Energy Sources presented in Fig.1.

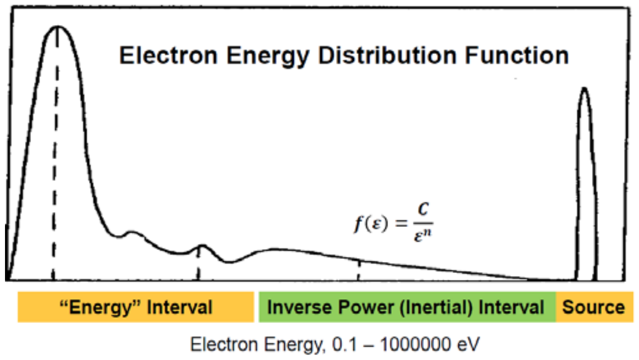

Fig.1a. EEDF in a gas under high energy source

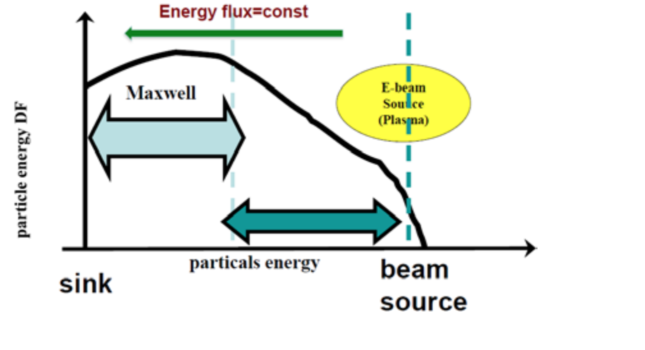

Fig.1b. “Energy”, “Inertial” and “Source” Intervals

Primary fast electrons are created by high energy source and move from right to left, they create cascades of secondary electrons which undergo to stopping in the region where energy flux is constant in energy space.

General properties UIPS may have not only inverse power law, but also 2 or more power laws and combination with exponential cutoff or curved power laws. UIPS have scale invariance, and could be checked by straight log-log lines as the signature of UIPS. The difference and main features of UIPS are in lack of well defined average values and moments, so it is necessary to develop special Grad moment expansion and formulating the hydrodynamic approximations. The Green function method could be applied to the solution of UIPS in a beam stopping. UIPS has the universality to different applications like deeper origin to dynamical processes, phase transitions in thermodynamic systems, e.a. Mathematical approach to UIPS include renormalization group theory, Pareto distributions based on CDF (cumulative distribution functions), PDF (probability density functions), MGF (moment generation functions) and CF (characteristic functions). Moreover it goes back to Einstein – Boltzmann definition of entropy by Gibbs or Thsalis.

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[1] This work was supported by Research conducted under the Russian Science Foundation Grant (Project No 14-50-00124)

RADIATION EFFECTS AND DEFECT ANNEALING IN FUNCTIONAL MATERIALS FOR FUSION APPLICATIONS

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The radiation-resistant oxide and halide insulators (MgO, Al_2O_3, $MgAl_2O_4$, BeO, MgF_2 etc) are important materials for applications in fusion reactors. It is very important to predict/simulate not only the kinetics of diffusion-controlled defect accumulation under neutron irradiation, but also a long-time defect structure evolution including thermal defect annealing after irradiation.

After introducing some basics on the radiation point defects in halides, binary oxides and oxide perovskites [1] as well as the mechanisms of point defect and metal colloid formation in thermochemically reduced (TCR) samples or under particle irradiation (neutron, ion, proton, electron), the current understanding of their thermal annealing is briefly reviewed.

We will shortly describe recently developed and successfully applied [2-4] theoretical approach based on the formalism of the correlation functions, describing spatial distribution of both similar (*F*-*F* centers) and dissimilar defects (a Frenkel pair of defects: an *F* center – an interstitial O_i ion) which allows us to study defect kinetics and aggregation much better than generally accepted rate equations or simple first order kinetics.

In particular, the kinetics of the *F*-type center annealing after electron, heavy ions or neutron irradiation was treated as the bimolecular process with equal concentrations of the complementary *F* and O_i defects. It is controlled by the interstitial oxygen ion mobility, which is much higher than that of the *F* centers. It is demonstrated how the shape of the *F*-annealing curves is determined by the two control parameters: migration energy E_a and effective pre-exponential factor, and strongly depends on irradiation fluence and other conditions.

The appropriate migration energies were obtained from available in literature annealing kinetics for electron, neutron and ion irradiated MgO, Al_2O_3, $MgAl_2O_4$, $Y_3Al_5O_{12}$, BeO, ZnO, YSZ, PLZT etc. The results obtained are used for evaluation of the interstitial oxygen migration parameters and compared with available *ab initio* calculations. Comparison with another type of experiments, such as *F*-type center annealing in TCR samples, will be also given for MgO, BeO, $MgAl_2O_4$ and YSZ. This allows us to find the activation energies for the *F* center migration.

Special attention is paid to: (1) dose effects on *F* center annealing in neutron and fast electron irradiated MgO and MgF_2; (2) a detailed comparison of diffusion-controlled *F* center thermal annealing in neutron, electron and heavy-ion irradiated MgO, MgF_2, Al_2O_3.

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PLASMADYNAMIC PROCESSES IN QUASI-STATIONARY PLASMA ACCELERATORS WITH ION CURRENT TRANSFER MODE PROVIDING THE FORMATION OF HIGH-ENERGY COMPRESSION PLASMA FLOWS FOR EFFECTIVE MODIFICATION OF MATERIALS SURFACE PROPERTIES

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Traditional plasma accelerators with an intrinsic magnetic field have reached a definite limit in their development, as the ways to increase parameters of plasma, generated by them, are practically exhausted. Quasi-stationary plasma accelerators of a new generation, operating in the ionic current transfer mode and performing ion-drift acceleration of magnetized plasma, are of great interest for creating high-energy plasma flows. In these systems, acceleration of plasma is accompanied by its compression due to interaction between longitudinal components of electric current and its azimuthal magnetic field. As a result, created at the outlet of the plasma accelerator discharge device is the compression plasma flow with plasma parameters much higher than those in the discharge device.

The basic principles of compression plasma flow formation in the several types of quasi-stationary plasma accelerators are considered. The concepts as to determinative influence of exchange processes in the accelerating channel of such accelerators on a character of a current distribution, and, therefore, plasma flow parameters are considered.

High plasma parameters of compression flows, coupled with their long duration, open up wide opportunities for efficient modification of material surface properties. The action of such flows upon different materials makes it possible to perform goal-oriented changes in structural-phase state, element composition, and mechanical properties of modified surface layers.

The capabilities of compression plasma flows for modification of constructional and instrument steels, light- and hard metal alloys as well as semiconductors are demonstrated.