Monday, July 5

10:00 Opening Ceremony

Chairman: Dr Evgenia Benova

10:15 MICROWAVE PLASMA TORCHES AND THEIR APPLICATIONS T2
Dr Francisco Dias, Instituto de Plasmas e Fusão Nuclear ̃ Laboratório Associado, Instituto Superior Técnico, Portugal I1

11:00 SURFACE WAVE DISCHARGES AS SOURCES OF "HOT" HYDROGEN ATOMS T2
Dr Elena Tatarova, Instituto de Plasmas e Fusão Nuclear ̃ Laboratório Associado, Instituto Superior Técnico, Portugal I2

Chairman: Dr Francisco Dias

16:00 SYNTHESIS OF FUNCTIONAL POLYSTYRENE-TYPE FILMS IN ATMOSPHERIC PRESSURE DIELECTRIC BARRIER DISCHARGE T2
Mr. Mihai Gabriel Asandulesa, Faculty of Physics, Alexandru Ioan Cuza University, Romania O1

16:25 POLY-DIAGNOSTIC VALIDATION OF SPECTROSCOPIC METHODS CASE STUDY ON MICROWAVE PLASMAS T2
Ms. Ekaterina Iordanova, Department of Applied Physics, Eindhoven University of Technology, The Netherlands O2

17:20 CALIBRATION OF ACTIVE AND PASSIVE SPECTROSCOPIC TECHNIQUES APPLIED ON ATMOSPHERIC MICROWAVE INDUCE DISCHARGE T2
Mr. Jose Maria Palomares, Departamento de Física, Universidad de Córdoba, Spain O3

Tuesday, July 6

Chairman: Dr Elena Tatarova

09:30 CHARACTERIZATION OF SURFACE WAVES PRODUCING MICROWAVE PLASMAS IN A COAXIAL STRUCTURE AT LOW PRESSURES T2
Dr Antonio Gamero, Departamento de Física,
Universidad de Córdoba, Spain I3

10:15 MICROWAVE N_2 – Ar PLASMA TORCH T2
Dr Julio Henriques, Instituto de Plasmas e Fusão Nuclear ̃ Laboratório Associado,
Instituto Superior Técnico, Portugal I4

11:30 EXCITATION OF MERCURY ATOMS IN NITROGEN POST-DISCHARGE T2
Prof. Frantisek Krcma, Faculty of Chemistry, Brno University of Technology,
Czech Republic I5

Chairman: Prof. Joost van der Mullen

16:00 STRUCTURE AND ELECTROCHEMICAL PROPERTIES OF TRACK MEMBRANES WITH A POLYMER LAYER OBTAINED BY PLASMA POLYMERIZATION OF ACETYLENE VAPORS T2
Dr Liubov Kravets, Joint Institute for Nuclear Research, Flerov Laboratory of Nuclear Reactions, Russia O4

16:25 FAST ICCD IMAGING OF ATMOSPHERIC PRESSURE PLASMA SOURCE DURING POLYMERIZATION OF STYRENE AND ACRILIC ACID T2
Dr Ionut Topala, Plasma Physics Laboratory,
Alexandru Ioan Cuza University, Romania O5

17:20 EFFICIENCY OF MICRON-SIZED PARTICLES HEATING IN HIGH ENTHALPY PLASMA JETS T2
Mr. Vyacheslav Shcherbakov, Joint Institute for High Temperatures of
Russian Academy of Sciences, Russia O6

17:45 MECHANISM OF CATHODE EROSION IN THE NEGATIVE CORONA DISCHARGE T2
Mr. Alexey Petrov, Joint Institute for High Temperatures of
Russian Academy of Sciences, Russia O7

Wednesday, July 7

Chairman: Prof. Frantisek Krcma

09:30 MICROWAVE MEASUREMENTS OF HIGH-FREQUENCY ELECTRICAL FIELDS IN DIFFERENT MEDIA – PRINCIPLES, METHODS AND INSTRUMENTATION T2
Dr Plamen Dankov, Faculty of Physics, Sofia University, Bulgaria I6

10:15 EMISSION AND LIF SPECTROSCOPY IN Ar-N_2 AND N_2 FLOWING AFTERGLOWS T2
Dr André Ricard, LAPLACE, University Paul Sabatier, France I7

11:30 POLY-DIAGNOSTICS AND MULTI MODELING; EXPLORATION OF NON-LTE PLASMA ASPECTS T3
Prof. Joost van der Mullen, Eindhoven University of Technology, The Netherlands I8

12:20 ADHESIVE PROPERTIES OF PTFE FILMS MODIFIED BY DC DISCHARGE T3
Dr Alla Gillman, Enikolopov Institute of Synthetic Polymer Materials, Russian Academy of Sciences, Russia O8

Chairman: Dr André Ricard

16:00 ANALYTICAL CALCULATION OF GAS TEMPERATURE AND MEASUREMENT OF ELECTRON TEMPERATURE FOR GAS DISCHARGE IN BINARY MIXTURES OF He AND Ne T3
Dr Krassimir Temelkov, Institute of Solid State Physics, Bulgarian Academy of Sciences, Bulgaria O9

16:25 ELECTROMAGNETIC WAVE MODES SUSTAINING COAXIAL DISCHARGE AT THE PRESENCE OF OUTER DIELECTRIC TUBET3
Mr. Todor Bogdanov, Faculty of Physics, Sofia University, Bulgaria O10

17:20 AXIAL DISTRIBUTION OF GAS DISCHARGE CHARACTERISTICS IN SURFACE-WAVE-SUSTAINED ARGON PLASMA COLUMN AT VARIOUS GAS PRESSURES T3
Mr. Kaloyan Pavlov, Faculty of Physics, Sofia University, Bulgaria O11

17:45 LANDAU DAMPING IN SPACE PLASMAS WITH TWO ELECTRON TEMPERATURE NON-MAXWELLIAN DISTRIBUTION FUNCTIONS T3
Dr Muhammad Qureshi, Department of Physics, GC University, Pakistan O12

Thursday, July 8

Chairman: Dr Radomir Panek

09:30 START-UP PHASE OF THE DISCHARGE IN TOKAMAKS T1
Dr Jan Stockel, Institute of Plasma Physics, Association EURATOM/IPP.CR, Czech Republic I9

10:15 RECENT ADVANCES IN THE STUDY OF LH-GENERATED FAST ELECTRONS IN THE SOL* T1
Dr Vladimir Fuchs, Institute of Plasma Physics, AS CR, Czech Republic I10

11:30 CREATION AND DYNAMICS OF PLASMA FIREBALLS T3
Prof. Gérard Degrez, Aero-Thermo-Mechanics Laboratory Université Libre de Bruxelles, Belgium I11

12:20 MODELING SURFACE KINETICS: ATOMIC RECOMBINATION AND MOLECULE CONVERSION T3
Dr Vasco Guerra, Instituto de Plasmas e Fusão Nuclear ̃ Laboratório Associado, Instituto Superior Técnico, Portugal O13

14:00 EXCURSION

Friday, July 9

Chairman: Prof. Ivan Zhelyazkov

09:30 PIC SIMULATIONS OF STRONGLY MAGNETIZED PLASMA DEPOSITION ON TOKAMAK WALLS T1
Dr Renaud Dejarnac, Institute of Plasma Physics, AS CR, Czech Republic I12

10:15 STATUS OF THE COMPASS TOKAMAK T1
Dr Radomir Panek, Institute of Plasma Physics, AS CR, Czech Republic I13

11:30 PLASMA POTENTIAL AND ELECTRON ENERGY DISTRIBUTION FUNCTION MEASURED BY LANGMUIR PROBE IN TOKAMAK EDGE PLASMA T1
Dr Tsviatko Popov, Faculty of Physics,
St Kliment Ohridski University of Sofia, Bulgaria I14

12:20 ADVANCED PROBE DIAGNOSTICS FOR MEASUREMENT OF ELECTROMAGNETIC PROPERTIES OF CURRENT FILAMENTARY STRUCTURES IN EDGE PLASMA OF THE TJ-II STELLARATOR AND COMPASS TOKAMAK T1
Mr. Karel Kovarik, Institute of Plasma Physics, AS CR, Czech Republic O14

Chairman: Dr Jan Stockel

16:00 NEW MODELS FOR PREDICTING PEDESTAL TEMPERATURE AND DENSITY IN ELMY *H*-MODE PLASMA T1
Ms. Wannapa Buangam, Department of Physics, Faculty of Science,
Mahidol University, Thailand O15

16:25 HYDROGEN RETENTION IN VOLUMETRIC CFC SRUCTURES T1
Mr. Arseniy Kuzmin, National Research Nuclear University MEPhI, Russia O16
GLOW DISCHARGE CLEANING OF OXYGEN CONTAMINATED STAINLESS STEEL T1
Mr. Yaroslav Sadovskiy, National Research Nuclear University MEPhI, Russia O16

17:20 POSTER SESION

POSITRON LIFETIME CALCULATION OF DEFECT IN PALLADIUM CONTAINING HYDROGEN AND HELIUM P1
Mr. Evgeni Popov, Institute for Nuclear Research and Nuclear Energy, BAS, Bulgaria

DEFECT ANNEALING IN PURE IRON AND PALADIUM MEASURED BY COINCIDENCE DOPPLER BROADENING SPECTROSCOPY P2
Mr. Kalin Berovski, Institute for Nuclear Research and Nuclear Energy, BAS, Bulgaria

THE SPECTRA OF HYDROGEN THERMAL DESORPTION FROM GRAPHITES AND THEIR INTERRELATIONS WITH IMPLANTATION AND RETENTION CONDITIONS P3
Mr. Alexey Ayrapetov, National Research Nuclear University MEPhI, Russia

Saturday, July 10

Chairman: Dr Tsviatko Popov

09:30 LASER DRIVEN ION ACCELERATION IN MASS LIMITED TARGETS T3
Prof. Alexander Andreev, SIC "S. I. Vavilov State Optical Institute", Russia I15

10:15 SIMULATION OF DEFECTS IN FUSION PLASMA FIRST WALL MATERIALS T1
Prof. Troyo Troev, Institute for Nuclear Research and Nuclear Energy, Bulgarian Academy of Sciences, Bulgaria I16

11:30 COMPUTER-SIMULATIONS OF POSITRON INTERACTION IN α-IRON CONTAINING EDGE AND SCREW DISLOCATIONS T1
Mr. Pavel Staikov, Institute for Nuclear Research and Nuclear Energy, Bulgarian Academy of Sciences, Bulgaria O17

11:55 INVESTIGATION OF MATERIALS FOR FUSION POWER REACTORS T1
Mr. Amine Bouhaddane, Slovak University of Technology, Faculty of Electrical Engineering and Information Technology, Slovakia O18

12:20 NON-DESTRUCTIVE RESEARCH METHODS APPLIED ON MATERIALS FOR THE NEW GENERATION OF NUCLEAR REACTORS T1
Ms. Iveta Bartošová, Slovak University of Technology, Faculty of Electrical Engineering and Information Technology, Slovakia O19

Chairman: Dr Renaud Dejarnac

16:00 INFLUENCE OF THE OBLIQUE MAGNETIC FIELD ON THE SECONDARY ELECTRON EMISSION FROM THE PLASMA FACING MATERIALS IN FUSION REACTOR T1
Ms. Irina Berezina, National Research Nuclear University MEPhI, Russia O20

16:25 LASER GUIDING THROUGH AN AXIALLY NON-UNIFORM COLLISIONAL PLASMA CHANNEL T1
Mr. Navpreet Singh, Department of Physics, Dr. B.R.Ambedkar National Institute of Technology Jalandhar, India O21

16:50 MODELLING AND SIMULATION OF GYROTRONS FOR ITER T1
Prof. Ivan Zhelyazkov, Faculty of Physics, Sofia University, Bulgaria O22

17:20 **CLOSING CEREMONY**

MICROWAVE PLASMA TORCHES AND THEIR APPLICATIONS

J. Henriques, N. Bundaleska, F.M. Dias, E. Tatarova, and C. M. Ferreira

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High-density plasma torches provide suitable conditions to dissociate molecules in the abatement systems and burn out chemical and biological warfare agents as well as to atomize materials. One of the main advantages of microwave plasma torches at atmospheric pressure is that they make it possible to inject large power densities into the plasma and thus to achieve high densities of active species of interest.

In this work we present an experimental and theoretical study of microwave (2.45 GHz) atmospheric pressure plasma torches driven by surface waves operating in gases of interest for several applications, namely air, air-water, mixtures containing pure H_2, N_2-Ar, and pure Ar.

In our study we shall make a comprehensive presentation of experimental setups, diagnostics, and applications of microwave plasma torches, namely in what concerns environmental ones, as for the abatement of hazardous and biological agents, and for the production of hydrogen from alcohols (ethanol and methanol) intended to achieve CO_2-free fuels.

Concerning diagnostics, we shall present experimental results obtained from radiophysics methods and optical emission spectroscopy. The latter have shown the presence of unusually hot hydrogen atoms in hydrogen-containing plasmas. A possible theoretical explanation is also presented.

SURFACE WAVE DISCHARGES AS SOURCES OF "HOT" HYDROGEN ATOMS

E. Tatarova, E. Felizardo, J. Henriques, F. M. Dias and C.M. Ferreira

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Surface waves discharges (long cylindrical plasma columns) are sustained by the electric field of a surface wave, which simultaneously propagates and creates its own propagation structure. Consequently, this type of discharge exhibits a large degree of non uniformities. The wave power is progressively dissipated by the plasma electrons along the wave path and the electron density decreases gradually towards the plasma column end. Diffusion to the walls causes a radial decrease in electron density, with the formation of radial dc field. Due to peculiarities of these discharges, radial and axial density gradients increase close to the plasma column end, with the consequent appearance of significant dc fields in this part of the discharge.

"Super hot" (with energy up to 8 eV) and "hot" (with energy ~ 0.3 eV) hydrogen atoms at pressure p = 0.01 mbar were detected throughout the volume of surface wave generated H_2 discharges operating at 500 and 350 MHz. Bi-Gaussian shape of the Balmer H_β, H_γ, H_δ, H_ε lines has been observed. The observed bi-Gaussian structure suggests the existence of two groups of atoms, i.e., a "hot" group, corresponding to the central peak, and a "super hot" one, corresponding to the broadened part. The average energy of the "super hot" atoms increases significantly along the discharge and the average energy is higher at 350 MHz than at 500 MHz. As is known, the sheath width and the dc electric field increase when the frequency decreases. The measured profiles change significantly along the radius (Abel inversion has been applied). The broader base expands towards the wall, indicating that even hotter H atoms are present in that region. Thus, these results provide some confidence to the idea that "super hot" H atoms in this type of discharge are generated near the wall.

SYNTHESIS OF FUNCTIONAL POLYSTYRENE-TYPE FILMS IN ATMOSPHERIC PRESSURE DIELECTRIC BARRIER DISCHARGE

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Immobilization of biological active species is a subject of great interest in the fabrication of biomedical systems. Several methods are employed including covalent coupling with activated supports, inclusion in microcapsules, and intermolecular cross-linking of enzymes by functional or multi-functional reagents. One of the most efficient and simple procedure for immobilization of biomolecules on polymeric substrates is the use of plasma polymerization reactions. The plasma polymerization is an attractive technique due to the unique properties of resulting ultrathin films such as good adhesion to substrates, controlled hydrophilic/hydrophobic character, well uniformity, time stability etc.

Polyethylene glycol-type polymerized films are widely used as substrates for protein adsorption onto medical devices. A disadvantage of these films is low stability in aqueous solutions. Alternatively, it can be obtained plasma co-polymerized films of ethylene glycol with a “neutral” monomer, like styrene. Polystyrene matrices are stable in aqueous solutions, therefore they are suitable for preservation of functional groups and offers good conditions for chemical fixation of biological molecules.

In this work, functional polystyrene-type polymerized films were obtained by plasma polymerization of a mixture of styrene and ethylene glycol using an atmospheric pressure dielectric barrier discharge (DBD). Electrical and optical diagnosis of the discharge was performed in order to find the optimum conditions for plasma polymerization process. It was found that DBD is working as a normal glow discharge and the specific regions of glow discharge, even at atmospheric pressure, were identified. The uniform radial distribution of the glow discharge and the plan-parallel geometry of our reactor offer favourable conditions for obtaining uniform thin films.

Chemical structure of functional polystyrene-type polymerized films was identified using Fourier transform infrared spectroscopy and X-ray photoelectron spectroscopy. The FTIR and XPS spectra confirm the presence of hydroxyl functional groups incorporated in the polystyrene matrix.

POLY-DIAGNOSTIC VALIDATION OF SPECTROSCOPIC METHODS; CASE STUDY ON MICROWAVE PLASMAS

E. Iordanova[1], J. M. Palomares[2], S. Hübner[1] and J.J.A.M. van der Mullen[1,2]

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In this work spectroscopic diagnostic methods have been applied to different microwave plasma sources, including the surfatron, the waveguide surfatron and the axial induced torch. The frequency of these microwaves equals in all cases 2.45 GHz. Different plasma settings are realized by changing the pressure, input power, gas flow and composition.

The applied spectroscopic methods can be divided into active and passive techniques.

Active spectroscopy refers to laser spectroscopy; more specifically to Thomson scattering (TS) and Rayleigh scattering (RyS). The TS method is used to determine the electron density and electron temperature, while RyS delivers information about the heavy particle density and temperature. These laser techniques are expensive and experimental demanding. Nevertheless, the interpretation of the results is in most cases straightforward.

For passive spectroscopy the opposite applies. The methods are experimentally relatively easy to perform but the interpretation is complicated and strongly depends on the degree of equilibrium departure. One of the ways to improve the interpretation of passive spectroscopy is to use absolute intensity measurements; meaning that the emitted and detected plasma radiation is calibrated against the radiation generated by a standard light source. This is done for both line and continuum radiation.

Absolute *line* intensities give the electron temperature whereas the electron density can be deduced form absolute *continuum* measurements. To take the departure form equilibrium into account a collisional radiative model has been used. The iterative combination of (the absolute measurements of) line and continuum radiation provides a new method to obtain the values of T_e and n_e simultaneously.

An important role in our poly-diagnostic study is played by Thomson scattering (TS). Since it simultaneously provides information of both n_e and T_e, while the interpretation of the data is straightforward it can be used to guide the interpretation of plasma emission. In this way the relation between plasma light and plasma properties can be established more firmly and the insights obtained can be used in industrial environments where plasmas are not accessible for laser techniques.

CALIBRATION OF ACTIVE AND PASSIVE SPECTROSCOPIC TECHNIQUES APPLIED ON ATMOSPHERIC MICROWAVE INDUCE DISCHARGE

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Gas discharges working in open air are a subject of a growing interest, due to their applicability in many fields such as waste treatment, surface treatment and biomedical applications. Of a particular importance are the cold atmospheric plasmas. They are small or micro-plasmas driven by a low power level with a low gas temperature T_g while the electron temperature T_e is high. These cold atmospheric plasmas have numerous possibilities in material processing and biomedical applications.

In this contribution, active and passive spectroscopic measurements performed on an atmospheric microwave induced plasma, created by a surfatron, are presented. The plasma is created open to the air at atmospheric pressure using argon as the main gas, where H_2 is introduced as an additive (0%-0.3%). Electromagnetic waves are generated at 2.45 GHz with power in the range 57-88 W. This atmospheric discharge is similar to a cold atmospheric plasmas but with higher gas temperatures. Two laser active techniques have been applied, Thomson and Rayleigh scattering, and two passive method namely Stark broadening and absolute intensity measurements. These methods provide values of the most important plasma parameters: the electron density and temperature, and the gas temperature.

The advantage of the active techniques is that the results are spatially resolved what opens the possibility to study in detail the behavior of the discharge and the effect of the hydrogen impurities. A disadvantage is that laser methods are experimentally demanding and expensive. Therefore it is useful to perform passive and active spectroscopy quasi-simultaneously on the same plasma condition and position. By means of this poly-diagnostic calibration the validity region of the passive spectroscopical methods can be established so that future studies can eventually be based on passive methods only, for which a standard equipment for spectroscopic measurements and a calibration source suffices.

CHARACTERIZATION OF SURFACE WAVES PRODUCING MICROWAVE PLASMAS IN A COAXIAL STRUCTURE AT LOW PRESSURES

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Gas discharges sustained by high-frequency traveling waves have been intensely studied during the last thirty years, and they are widely used in numerous technological applications. Most of the theoretical and experimental works deal with surface wave propagating in cylindrical structures, in which the plasma column is sustained by the electromagnetic wave traveling mainly along the interface between the plasma and the surrounding dielectric tube [1]. Surface-wave discharges can be also maintained with a tubular structure, where the plasma is produced between an inner and outer radius [2]. In this structure, the tubes can be dielectric or conductor ones [3]. If the tubular plasmas present two plasma-dielectric interfaces, two azimuthal surface-wave plasma modes exist associated to each boundary in a certain sense [4], [5]. When an inner central conductor is added, tubular plasma in a coaxial structure is obtained.

This work shows the experimental characterization of the surface waves producing a microwave argon plasma column at low pressures in a coaxial structure. In this configuration the tubular discharge is located inside an external dielectric tube and outside an internal dielectric tube, in which a central metallic rod exists. All the system is surrounded by an outer cylindrical metallic guide.

The coaxial structure makes the plasma and the wave properties significantly different from those obtained without a central conductor. In fact, due to the electric field components, the coaxial propagating structure may not need a conventional wave launcher to excite a surface wave. In our case, the wave excitation can be achieved by making the coaxial structure to be the continuation of the power feeding coaxial cable.

The radial, azimuthal and axial profiles of the electric field are investigated under different experimental conditions to characterize the surface wave propagation. The results are compared with those obtained from a theoretical model for the propagation of the surface waves. For the modelling, the plasma is considered as a dielectric media radially homogeneous. The dispersion curve for the different modes is obtained by solving the Maxwell's equations under the appropriated boundary conditions [5].

References

[1] M. Moisan, A. Shivarova, A.W. Trivelpiece. Plasma Phys. Control. Fusion, 24 (1982) 1331

[2] X.L. Zhang, F.M. Dias, C.M. Ferreira. Plasma Sources Sci. Technol., 6 (1997) 29

[3] S. Letout, L.L. Alves, C. Boisse-Laporte, P. Leprince. J. Optoelectron. Adv. Mater., 7 (2005) 2471

[4] Z. Neichev, E. Benova, A. Gamero, A. Sola. Journal of Physics: Conference Series, 44 (2006) 133

[5] O. Leroy, P. Leprince, C. Boisse-Laporte. In *Microwave Discharges. Fundamentals and Applications* (Ed. Yu.A. Lebedev), Yanus-K, Moscú (2006) 137.

MICROWAVE N_2 – AR PLASMA TORCH

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The development of microwave based plasma sources operating at atmospheric pressure is an important issue for various industrial and scientific applications. Efficient applications of such sources depend on the ability to control the plasma properties. In the present work, a complex investigation of a surface wave driven N_2-Ar microwave plasma torch operating at atmospheric pressure is presented. The main plasma and wave characteristics are obtained in the framework of a self-consistent 2D model that describes the space structure of this plasma source. The system of equations considered to describe the plasma source include: Maxwell's equations; the dispersion of the surface mode; the rate balance equations for vibrationally excited states of electronic ground state molecules $N_2(X^1\Sigma_g^+, v)$; the rate balance equations for the triplet $N_2(A^3\Sigma_u^+, B^3\Pi_g, C^3\Pi_u)$ and singlet $N_2(a'^1\Sigma_u^-, a^1\Pi_g, w^1\Delta u, a''^1\Sigma_u^+)$ electronic excited states of the nitrogen molecule and the Ar($3p^5 4s$) and Ar($3p^5 4p$) excited states of Argon atoms; the rate balance equations for $N^+, N_2^+, N_4^+, Ar^+, Ar_2^+$ ions and electrons; the rate balance equations for the ground state N(^4S) and the metastable states N(^2P, ^2D) of nitrogen atoms; the gas thermal balance equation; the equation of mass conservation for the fluid.

The theoretical results have been validated by experiment. The surface wave induced microwave (2.45 GHz) plasma torch was created using a conventional surfaguide-based setup. A spectroscopic imaging system was used to measure 2D(r, z) profiles of emission intensities and line profiles. Abel inversion has been applied to derive the radial profiles from the side-on measurements. The H_β line profiles (Lorenzian components) have been measured to determine the electron density. The experimental 2D maps of the main plasma characteristics, like electron density, gas temperature etc., are in good agreement with the theoretical predictions.

EXCITATION OF MERCURY ATOMS IN NITROGEN POST-DISCHARGE

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Nitrogen post-discharges in various configurations have been subjects of many studies during last fifty years. Besides laboratory and technological plasmas, the nitrogen post-discharge is studied also in the kinetics of upper Earth atmosphere (corona borealis) and these processes are also taken into account in some extraterrestrial systems, for example in Titan atmosphere. The neutral nitrogen molecule can form many electronic states. Due to its symmetry, all vibrational levels of the ground state and also the first eight levels of the first electronically excited state are metastables. Besides them, there are some other strongly metastable highly excited states. All these states conserve the excitation energy for a long time over many seconds depending mainly on pressure. The excitation energy transfer during the collisions among these species as well as atomic recombination processes lead to formation of some radiative states and the visible light emission can be observed up to one second after switching off an active discharge depending on the experimental conditions, mainly on pressure. The real life time of metastable excited species can be dramatically decreased if any impurities are introduced into pure nitrogen. Besides the impurities containing oxygen and carbon, influences of some metallic atoms were observed, too. The presented work reviews our results obtained in pure nitrogen containing mercury atoms. The emission of atomic lines in the active discharge is nowadays applied as a standard technique (named as the glow discharge optical emission spectroscopy; GD-OES) for the analysis of metallic samples composition. But some of the metallic lines could be observed even during the post-discharge period.

The work presents results obtained during spectroscopic observations of DC flowing post-discharges of pure nitrogen plasma and nitrogen plasma containing mercury traces. Mercury was introduced into the system using auxiliary pure nitrogen flow enriched by mercury vapor. The introduction point was moved during the post discharge up to decay time of 40 ms, the post-discharge radiation up to 50 ms was studied by the emission spectroscopy in the range of 320–780 nm. The discharge tube around the observation point (± 3 cm) could be immersed in liquid nitrogen for the determination of temperature effect, too. The total gas pressure was 1000 Pa and the discharge current was kept at 100 mA.

Three nitrogen spectral systems (first and second positive and first negative) and NO^{β} bands were identified at all conditions. Besides them, the mercury line at 254 nm was recorded with the intensity depending on the mercury vapor introduction positions. No mercury lines were observed in the involved spectral region. The creation of mercury $^3P_1$ state that is the upper state of the observed mercury spectral line is possible by the resonance excitation energy transfer form vibrationally excited nitrogen ground state $N_2(X\,^1\Sigma_g^+, v = 19)$. The contemporary experiments did not confirm the other possible process responsible for the excitation of mercury line at 186 nm. The observed results should form a background for the development of a new titration technique used for the highly vibrationally excited nitrogen ground state molecules determination.

Acknowledgements

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STRUCTURE AND ELECTROCHEMICAL PROPERTIES OF TRACK MEMBRANES WITH A POLYMER LAYER OBTAINED BY PLASMA POLYMERIZATION OF ACETYLENE VAPORS

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The structure and the charge transport properties of 'diode-like' polymer composite membranes that possess asymmetry of conductivity in electrolyte solution – a rectification effect similar to that of a *p-n* junction in semiconductors were studied. To produce membranes with 'diode-like' properties, a thin semipermeable polymer layer formed by plasma polymerization of acetylene vapors was deposited on the one side of a porous substrate. As a porous substrate a poly(ethylene terephthalate) track membrane with a thickness of 10.0 μm and a pore diameter of 65 nm (pore density of 3×10^{9} cm^{-2}) was used. To produce the membrane, a poly(ethylene terephthalate) film was irradiated with krypton positive ions, accelerated in the cyclotron, and then subjected to physicochemical treatment on a standard method. The deposition of the polymer film on the membrane surface from acetylene vapors was done in a plasma-chemical reactor using a RF-discharge (13.56 MHz) in parallel plate configuration under a discharge power of 20 W and a gas pressure of 1.2×10^{-1} mbar. For study of the samples microstructure as well as the definition of the pore diameter on the membrane surface a method of scanning electron microscopy was used. Measurements of the current-voltage characteristics of the membranes were carried out with a direct current regime in the voltage range of –1 to +1 V using a PC-controlled potentiostat 'Elins P-8S' with a scan rate of 100 mV/s. A two-chambered cell with Ag/AgCl electrodes, containing a water solution of potassium chloride of identical concentration on both sides of the membrane was used for this purpose.

It is shown that the appearing of the 'diode-like' properties for composite membranes formed by this way can be explained by the presence in the membranes of two layers with functional groups of different natures and also by the change of the pore geometry. Such behavior of the formed membranes allows one their use as an electrical valve. Moreover, it is shown that the variation of the semipermeable layer thickness by method of plasma polymerization as well as the modification of the electrochemical properties of plasma treated membranes by chemical doping allows one to produce a wide spectrum of polymer composite membranes with asymmetric conductivity. Such membranes can be used to create chemical and biochemical sensors.

FAST ICCD IMAGING OF ATMOSPHERIC PRESSURE PLASMA SOURCE DURING POLYMERIZATION OF STYRENE AND ACRILIC ACID

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Atmospheric pressure glow discharge is a recent topic in the plasma physics research. In 2005, J.R. Roth makes reference to an internet search on “atmospheric glow discharge” that returned around 120 results. A new search using the same sentence at the end of 2009 revealed more than 46000 results. This is only a rough validation of the increasing scientific and technological interest on atmospheric pressure glow discharges. Applications with high economic and social potential are developed continuously in the research facilities and transferred to industrial partners: surface modification, thin films deposition, decomposition of chemical and biological contaminants, excimer generation and plasma medicine.

Plasma polymerization at atmospheric pressure becomes lately an alternative solution to chemical techniques (e.g. spin-coating, surface adsorption, grafting) to obtain functional coatings for different applications. These thin polymer layers are used for surface engineering of both, inorganic and organic substrates, to enhance chemical selectivity and to modify different surface properties in applications such as biotechnology, tribology, chromatography, chemical sensors and separation technology.

Physics and chemistry of atmospheric pressure glow discharge in presence of polymerizable compounds is not completely understood and some aspects are still under investigation. From the point of view of reaction mechanism, under plasma conditions, the monomer molecules gain energy from electrons, ions, photons and they might be fragmented into radicals, which recombine and rearrange, resulting in molecules growing to large molecular-weight. These processes take place in gas phase or at the surface of substrates with different kinetics. In particular case of glow discharge, due to well know regions with considerable differences in particles energy (e.g. negative glow and positive column), fragmentation and polymerization of monomer molecules is a subject of great interest for reaction mechanism and processes optimization.

We present in this study results obtained from fast ICCD imaging of a dielectric barrier discharge working in a mixture of helium and polymerizable gas (styrene or acrylic acid). We found that the discharge works in the glow mode at atmospheric pressure. Despite of presence of polymerizable compounds, the glow mode is preserved and no transition to filamentary regime was observed. Specific regions of glow discharge were pointed and even striations of positive column can be observed.

Spatio-temporal evolutions of total emitted light from the discharge are discussed for “pure” helium and helium mixture with styrene and acrylic acid. Distribution profiles of selected species, carrying information on the energy in the discharge gap, are discussed and specific parameters, like vibrational and rotational temperature, are calculated.

EFFICIENCY OF MICRON-SIZED PARTICLES HEATING IN HIGH ENTHALPY PLASMA JETS

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Heterogeneous plasma flows are widely used for heating of particles and plasma spraying. Wide temperature and dynamic range of plasma jets, the possibility of using different working gases allow combining in a single technological process phase and chemical transformations to ensure the desired modification of the initial powders and coating materials with a given structure [1].

Purpose of this study is to determine the efficiency of heating metal and dielectric particles with a size of 10-100 microns in the plasma jet. Study of heating such particles is of practical importance for many technological processes, one of which is plasma spraying. The Joint Institute for High Temperatures RAS established experimental facility to study the processes of plasma spraying, in which a DC electrical arc is used as the plasma generator [2]. The particles of sprayed material injected into the plasma stream through the holes near the tip of the cathode, which allows using of near-cathode region - region with a maximum temperature of the plasma to heat the particles.

Installation of plasma spraying has the following characteristics:
pressure in chamber from 100 to $50 \cdot 10^3$ Pa, plasma-forming gas - a mixture of αAr + (1-α) N_2 with a variable weight fraction α,%., flow rate of plasma gas G_g = 1,5-5 g/s, flow rate of transport gas (usually argon) - G_{tr} = 0,05-0,25 g/s, powder - G_p = 0,05-0,20 g/s, arc current I_d = 200-450A, the voltage arc U_d = 30-120V, expanding diameter of anode channel from 4 to 12 mm, nozzle output - 12-20 mm.

As the diagnostic systems used on this installation, high speed and high-sensitivity cameras operating in the optical and infrared spectrum, q-switched laser to illuminate the particles on a "laser knife" and a spectrometer that is used to determine the parameters of the plasma with particles as well as without them [3].

Experimental data on temperature, velocity, particle size were compared with their calculated values obtained by modeling of particles motion, heating and evaporation in the channel of plasmatron with the known from spectroscopic measurements spatial distributions of plasma parameters. In calculating of particles heating conductive - radiative model is used, taking into account the opacity of the particles at high temperatures [4].

[1]. Fauchais P., Understanding plasma spraying, Topical review, J. Phys. D: Appl. Phys. 37 (2004) R86–R108

[2]. Isakaev E.H., Grigor'yanc R.R., Spektor N.O., Tyuftyaev A.S. Vliyanie raskrytiya kanala vyhodnogo elektroda na harakteristiki plazmotrona. High Temp. 1994. V.32. № 4. P.627

[3]. Belyaletdinov T. Sh., Goryachev S. V. Senchenko V. N., Chinnov V. F., Shcherbakov V. V. Issledovanie gomogennoy i geterogennoy plazmy metodami spektroskopii i skorostnoy vizualizacii. Vestnik MEI, 2009, №4, P.61

[4]. Dombrovsky, L.A., Ignatiev, M.B., An estimate of the temperature of semitransparent oxide particles in thermal spraying. Heat Transfer Eng. 2003. 24, 60–68.

MECHANISM OF CATHODE EROSION IN THE NEGATIVE CORONA DISCHARGE

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Cathode erosion has been investigated in the Trichel pulse and glow mode of negative corona discharge in ambient air in the point-to-plane electrode geometry. Cathodes made of copper, graphite, aluminum, silicon, tungsten and silver have been used. Surface erosion in form of nanometer-scale craters and fractures, as well as the formation of nanometer-size oxide crystals on the cathode surface was found.

Experimental observations of the cathode during discharge by use of telemicroscope, fast-resolution discharge oscillography and electron microscopy let to conclude that formation of the erosion picture is guided by three processes. The first one is the spatio-temporal behavior of the discharge spot on the cathode surface. The second process is the local action of the discharge on the surface. The third one is the dynamics and redeposition of the erosion material in the gap.

Cathode erosion always occurs in a local manner – that is erosion processes happen in the point of the discharge localization on the cathode surface. Spatio-temporal behavior of the corona spot finds the dynamics of the erosion center on the surface [1]. Correlation between cathode spot dynamics, electrical characteristics of the Trichel pulses and erosion pattern was experimentally found. Trichel pulse parameters been plotted in the form of the amplitude-pulse time separation characteristics demonstrate independent action of surface processes and gap properties on the Trichel pulses.

Erosion of the cathode surface is caused by electro-explosive processes. Each erosion event is associated with a single Trichel pulse. Each Trichel pulse causes the formation of an erosion crater with diameter 40-100 nm [2]. Trichel pulse current runs the boundary between plasma and metal trough the surface of an elementary erosion crater. The current density is on the order of 10^8 A/cm^2. It causes the electro-explosive destruction of the surface material due to fast Joule heating. Note that energy of positive ions in the negative corona is no more than 10 eV and is insufficient for explanation of the observed erosion rate of graphite cathode on the order of 1 at/ion [3].

Formation of nanocrystals was found on the cathode surface as result of erosion material redeposition on the Cu and Ag cathodes [2]. No redeposition was observed on Au, Si, Al and graphite cathodes. The numerical model of the erosion material dynamics has been elaborated. Redeposition is caused by the electrostatic attraction of the thermionically charged erosion nanoclusters.

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1. Amirov R.H, Petrov A.A., Samoylov I.S.,”Effects of the Dynamics of Cathode Spot on Trichel Pulses”// International Journal of Plasma Environmental Science and Technology, volume 3, N.1, 2009, pp. 35-38.
2. Petrov A.A., Amirov R.H., Samoylov I.S.,”On the Nature of Copper Cathode Erosion in Negative Corona Discharge” // IEEE – Transactions on Plasma Sciences, volume 37, issue 7, 2009, pp.1146-1149.
3. Alexey A. Petrov, Ravil H. Amirov, Erik I. Asinovskii and Igor S. Samoylov, Electro-Explosive Mechanism of Carbon Cathode Destruction in Negative Corona Discharge in Trichel Pulse Regime // J. Plasma Fusion Res. Series, Vol. 8, 2009, pp. 780-783.

MICROWAVE MEASUREMENTS OF HIGH-FREQUENCY ELECTRICAL FIELDS IN DIFFERENT MEDIA – PRINCIPLES, METHODS AND INSTRUMENTATION

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The main types of microwave measurements are connected with five basic groups of parameters: power, frequency, spectrum, S-parameters and noise. Therefore, the measurement of the high-frequency electrical (E-) field (complex magnitudes and their distribution) in different media and structures is not a primary type of measurement, but it is very important for many applications. First of all, the extremely popular *EMC measurements* (Electro-Magnetic Compatibility) are based on determination of the electric/magnetic fields or power-density flux around microwave transmitters and the penetrations of these fields into the biological tissues (SAR – Specific Absorption Rates). The *antenna measurements* are the next big group of measurements based on determination of the E-fields around the transmitted/received antennas. The third important group of measurements, partially based on the electromagnetic fields' distribution, is connected with the *dielectric characterization of variety of materials and propagation media*: crystals, liquids, powder materials, absorbers, substrates for electronics, multi-layer materials, thin films (incl. nano-films), etc. In this group we can add the determination of the electron density and similar gaseous plasma parameters by microwave resonance methods.

In this lecture we present a brief review of the principles, methods and instrumentation, connected with the microwave measurements of the high-frequency electrical fields and some of their applications. In the first part, the standardization, units and RF-field sensors (1D and 3D) are considered and a very popular EMC example is presented for an illustration – the determination of the safety rates around GSM base station. Then the lecture continues with a short presentation of the microwave antennas: main characteristics, types of antennas and antenna arrays, principles of measurements in the far-field zone, etc. Very important is the implementations of the "near-field measurements" with several interesting examples. The principles of electromagnetic simulations of antennas and propagation media are also discussed in this part; several examples for simulations, based on method of moments (MoM), finite-element methods (FEM) and finite-different time-domain methods (FDTD), etc., are given and compared. Finally, the basic equipment for EM-field measurements is considered – for magnitude only and for magnitude and phase measurements.

The second part of the lecture is dedicated to the characterization of the dielectric properties of different materials and media, based on resonance, transmission-line and free-space methods. Several examples for modern measurement methods and equipment for characterization of dielectric substrates and crystals, liquids, powders, absorbers, etc. are presented and illustrated. Then the author's "two-resonator" method for determination of the dielectric anisotropy is described and examples for the measured anisotropy of some microwave substrates and multi-layer materials for antenna radomes are presented. Finally, an example for determination of the electron density in high-pressure gaseous plasma by hairpin-resonator probe is presented and some results are discussed.

EMISSION AND LIF SPECTROSCOPY IN Ar-N_2 AND N_2 FLOWING AFTERGLOWS

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Abstract

Production of N_2(B,v') states is analysed from the N_2, 1st pos. intensity in Ar-N_2 and N_2 afterglows of microwave and Corona discharges.
In Ar-N_2 afterglows of microwave discharges , the N_2(B,v') distribution is depending on the N_2 percentage into Ar . In pure N_2 afterglows at pressure up to the atmospheric gas pressure, it is found that the N_2(B,11) state is mainly populated by the N+N atom recombination along the $N_2(^5\Sigma_g)$ weakly attractive curve .The other N_2(B,v'>0) states are also produced by the N+N atom recombination, but via the $N_2(A^3\Sigma^+{}_u)$ strongly attractive curve.
Variations of N-atom density versus the x-percent in Ar-xN_2 microwave afterglows have been obtained by TALIF.
A strong emission at 1040 nm from the N_2(B,0-A,0) band is obtained in Corona N_2 afterglow. Such an emission is largely stronger than in microwave afterglows at low N_2 pressure and at atmospheric Ar-x N_2 gas pressure with x=1.5-23 % .
An interpretation of this result at atmospheric N_2 gas pressure is given by desexcitation of vibrational levels of N_2(A, W) states at the benefit of the N_2(B,0) state in Corona and DBD afterglows.

POLY-DIAGNOSTICS AND MULTI MODELING; EXPLORATION OF NON-LTE PLASMA ASPECTS

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The success of plasma technology with its steadily increasing number of applications is mainly based on the fact that plasmas can create large fluxes of photons and radicals. In many cases these transport fluxes are large enough to create deviations from equilibrium; and in general we can state that the larger the effluxes, the larger the departure form equilibrium will be, the more the various plasma aspects are decoupled form each others, and the higher the need to calculate the different species independently in density, momentum and energy. So, in the study of large efflux producing plasmas we can by no means rely upon the laws of equilibrium statistical thermodynamics.
This certainly applies to the field of Cold Atmospheric Pressure Plasmas.

Multi modeling
To get insight into plasmas in-depth theoretical studies are needed and models have to be constructed. In a first approach we can divide a plasma model into three blocks:

Chemistry, Energy coupling and Transport.

If the conjunction of these three building blocks is solved self-consistently on a grid of 1, 2 or 3 dimensions we speak of a ***Grand Model***.

Especially the Chemistry plays a crucial and complicating role. The (non-equilibrium) composition of the plasma determines the source terms and the transport coefficients like the coefficients for internal friction (diffusion), viscosity and heat and electrical conductivity. Thus both Energy coupling and Transport strongly depend on Chemistry. This becomes evident with the following example: An atmospheric microwave induced plasma working on pure argon is in most cases filamentary in structure. However, by adding small quantities of xenon and/or nitrogen the filaments can melt together making the plasma more robust in volume. So, a small change in Chemistry can alter the plasma Transport and Energy coupling drastically.
An additional complication offered by the Chemistry block is that the calculation of the different species demands for the computation of many different reaction paths that may differ substantially in reaction times. This makes the solution of the set of differential equations that form the bases of a Grand Model to a stiff problem.

Nowadays several types of so-called ***Global Models*** are constructed. In these models the chemistry is reduced into main reaction paths while the transport is replaced by diffusion rates determined by the size of the plasma. So, in fact global models are zero dimensional models that offer (quasi analytical) relations between the control parameters like pressure, fill chemistry and power on the one hand and internal properties like electron density and temperature on the other hand. They do not give insight in the spatial distribution of plasma species; for that a Grand model must be employed.

In this contribution we will give an example of the Grand model-construction platform PLASIMO and discuss some Global models. Apart from that we will present a Plasma Characterization method named ***disturbed Bilateral Relations***. By relating equilibrium disturbing to restoring mechanisms this method of dBR generates validity-criteria and predicts trends in the deviations from equilibrium.

Polydiagnostics

Models and theories have to be validated by experiments but since the various experimental methods have their limitations we can not stick to one method solely; in stead we have to compare the results of the various methods with each other.

This so-called polydiagnostic approach provides insight in the validity regimes of the various methods, it relates these to the state of equilibrium departure and .. it gives information of the plasmas under study.

In this contribution we will confine ourselves to optical emission spectroscopy methods that can be divided into ***passive and active*** methods. Passive spectroscopy has the advantage that only the light produced by the plasma is analysed. So, in contrast to for instance electrical probe measurements, the method is non-intrusive. However, the interpretation of the line and continuum radiation in terms of the main plasma properties is far from simple. In general we need models to account for the departure from equilibrium. Less sensitive to equilibrium departures is the interpretation of continuum radiation. However, we will show that the classical method of line/continuum ratios is not valid in non-LTE conditions. Passive spectrometry has to be performed absolutely, that is calibrated against a standard radiation source.

Thomson Scattering (TS) is an ***active*** spectroscopic technique that allows the simultaneous determination of the electron density and temperature, n_e and T_e. This method is based on the scattering of laser photons by free plasma electrons. It can be considered as a direct technique since the interpretation of the TS results does not depend on the state of equilibrium-departure. Moreover, TS also gives accurate results of n_e and T_e with high spatial and temporal resolution. However TS has the disadvantages that it is experimentally demanding and expensive. The main reasons is that the cross section for the interaction between free electrons and photons is very small ($\sim 10^{-29}$ m^2); thus the scattering process is very inefficient and TS photons are easily drawn in the signal created by Rayleigh scattering or false stray light.

As a case study we will apply both active and passive spectroscopy on atmospheric microwave produced argon plasmas and the comparison will show that

- the Boltzmann plot method based on relative intensities gives erroneous results,
- better results are obtained if the measurements are performed absolutely,
- the effect of equilibrium departure has to be taken into account,
- the combination of absolute line and continuum measurements gives n_e and T_e,
- the T_e value obtained by TS are in general larger.

ADHESIVE PROPERTIES OF PTFE FILMS MODIFIED BY DC DISCHARGE

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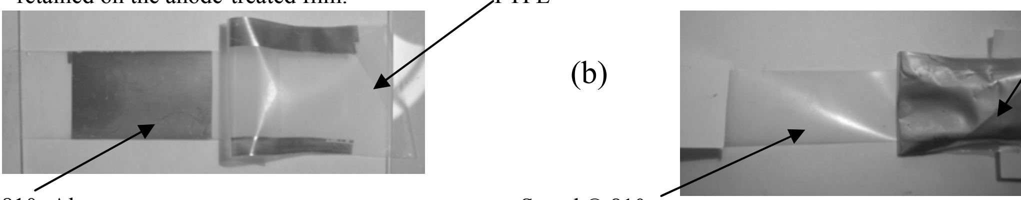
Novel express procedure has been developed for determination of the quantitative adhesion characteristics of the modified surface of polymer films, especially those treated by the low-temperature plasma for vacuum metallization. The procedure comprises deposition of aluminum layer having ~ 100 nm in thickness by means of thermal evaporation of Al in vacuum, making an adhesive joint between Al layer on the film and standard Scotch® 810 tape. Then, T-peel testing of the specimen was performed using Autograph AGS-10 KNG (Shimadzu) universal testing machine at a crosshead speed of 100 mm/min. As a result, a curve reflecting change in the peel resistance (***A***) along the sample length was obtained. The representativeness of this procedure was established on the basis of the data on the peel strength of two Scotch® 810 tape specimens being joint by their adhesive layers. The ***A*** value in this case was 198±5 N/m.

The adhesion characteristics were examined for the PTFE film of 40 μm thickness and the film of copolymer of vinylidene fluoride with ethylene [poly(VDF-*co*-E)] of 50 μm thickness. The measurements were performed as for the initial films as for the films modified by DC discharge. The film samples were placed on the cathode or on the anode and treated in the flow mode at the residual pressure of 13.3 Pa (air), and the discharge current of 50 mA for 60 s. A change in the surface properties was characterized by values of the contact angle (θ) determined with a goniometer (error ± 1°) using two test liquids, double distilled water and glycerol. From the results, the work of adhesion (W_a), the total surface energy (γ) as well as it's polar (γ^p) and dispersion (γ^d) components were calculated. It was found that the fluoropolymer films treated under these conditions have low values of θ and high values of W_a, γ and γ^p.

It was shown that the DC discharge modification substantially increases ***A***, and the highest peel strength of the Al layer being observed for the anode treated film. For the initial PFTE film the ***A*** value (Scotch® 810/Al) is equal to 78±18 N/m, and for the anode treated film this parameter is 169±15 N/m. The photographs of the specimens of the initial and anode-modified PTFE films after T-peel testing are shown that the Al metal layer is almost completely pulled off by the Scotch® 810 tape from the initial PTFE film but it is fully retained on the anode-treated film.



Photographs of the specimens of the initial (a) and anode-modified (b) PTFE films after T-peel testing.

The results obtained show that plasma treatment substantially alters the adhesion properties of PTFE film surface, and the procedure proposed can successfully used for quantitative evaluation of the adhesion characteristics of the surface of plasma-modified thin polymer films.

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ANALYTICAL CALCULATION OF GAS TEMPERATURE AND MEASUREMENT OF ELECTRON TEMPERATURE FOR GAS DISCHARGE IN BINARY MIXTURES OF He AND Ne

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One of the main problems in plasma physics is the determination of characteristic constants for basic processes in plasma, such as asymmetric charge transfer, Penning ionization, diffusion, heat conduction and electron-heavy particle collisions, which are fundamentally important and widely used in gaseous discharges, laser physics, plasma technologies, gas-discharge mass spectroscopy, absorption and emission spectroscopy, and plasma in general. Characteristic constants for the heavy particle interaction depend on the gas temperature. Experimental techniques for gas temperature determination using measurements of Doppler broadening of spectral lines and focal distance of thermal lens are definitely imprecise. Electron impact excitation, de-excitation and ionization, as well as three-body recombination, thoroughly depend on the electron temperature. Measurements of electron temperature by a Langmuir probe are not suitable for pressures above 10 Torr, particularly in high-voltage and high-current pulsed longitudinal discharges. In the literature there are several models of varying degrees of complexity, which predict, among the other parameters, values of electron temperature with considerable variation, and furthermore there is no overlap.

Thermal conductivities of Ne-He binary gas systems are obtained on the base of experimental data fit, rigid sphere and 12-6 Lennard-Jones inter-atomic interaction approximations. Assuming that the gas temperature varies only in the radial direction and using the calculated thermal conductivities, analytical solution of the steady-state heat conduction equation is found for two cases of uniform and non-uniform power input. For both cases the average gas temperature is found by averaging the radial gas temperature distribution over the radius.

Measurement of the relative intensities of some He and Ne spectral lines, originating from different upper levels has enabled us to determine the average electron temperature. It is verified that the experimental results are in quantitative agreement with the average electron temperature predicted of the existing self-consisting models. The discrepancy is less than 0.05 eV.

ELECTROMAGNETIC WAVE MODES SUSTAINING COAXIAL DISCHARGE AT THE PRESENCE OF OUTER DIELECTRIC TUBE

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Microwave discharges sustained by travelling electromagnetic waves are investigated in the past decades both theoretically and experimentally. The coaxial structure is relatively new type of plasma source, which was proposed recently [1,2]. In the coaxial structure the plasma, which is both radially and axially inhomogeneous, is produced outside the dielectric tube in a low-pressure dielectric or metal chamber. Usually a metal rod is arranged at the dielectric tube axis. The basic relation in our model is the local dispersion relation obtained from Maxwell's equations [3]. Since the plasma density decreases from the launcher in axial direction while the wave frequency is constant, the local dispersion relation gives the dependence between the normalized plasma density and the dimensionless wave number, the so called phase diagrams. Such configuration is studied by C. Boisse-Laporte for the case of homogeneous plasma. A modelling of the radial structure is presented by L. L. Alves [4].

The purpose of this work is to investigate theoretically the propagation characteristics of the electromagnetic wave that can produce and sustain plasma in a coaxial structure, as well as the wave field components at various wave modes on the base of one-dimentional axial model. We have investigated the coaxial structure which consists of two axial dielectric tubes with a metal rod in the axis. The plasma takes place between the two tubes. The behavior of the phase diagrams and the wave field components is compared in different configurations depending on geometric factors.

References

[1] E. Räuchle, J. Phys. IV France **8,** 99 (1998)

[2] S. Gritsinin, I. Kossyi, N. Malykh, M. Misakyan, S. Temchin, and Y. Bark, Preprint No 1, Russian Academy of Science, General Physics Institute, Moscow, 1999

[3] E. Benova, Z. Neichev, Czechoslovak J. Phys. 52, D659-D665 (2002)

[4] L. L. Alves, C. Boisse-Laporte, O. Leroy and G. Gonsset, in *Proc. 15th International symposium on Plasma Chemistry*, Vol. IV, edited by A. Bouchoule, J. M. Pouvesle, A. L. Thomann, J. M. Bouchire and E. Robert (Gremi, CNRS/ University of Orleans) (2001) p. 1251 – 1256

AXIAL DISTRIBUTION OF GAS DISCHARGE CHARACTERISTICS IN SURFACE-WAVE-SUSTAINED ARGON PLASMA COLUMN AT VARIOUS GAS PRESSURES

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Argon plasma column sustained by travelling electromagnetic surface wave is theoretically studied by means of self-consistent model. The model is based on self-consistently linked kinetic and electrodynamic sets of equations describing both the gas discharge properties and the wave propagation characteristics along the axially inhomogeneous plasma column. A steady-state Boltzmann equation in an effective field approximation coupled with a collisional–radiative model for argon discharge is numerically solved together with Maxwell's equations for an azimuthally symmetric TM surface wave. The argon ground state and seven excited states (4s, 4p, 3d, 5s, 5p, 4d, 6s) considered as blocks of levels are taken into account. The axial profiles of the electron number density and the densities of argon excited states as well as the densities of the atomic Ar^+ and molecular Ar_2^+, Ar_3^+ ions are obtained and compared with available experimental data. 3D plot of the EEDF and axial profiles of the mean electron energy, mean power per electron, effective electron–neutral collision frequency are also presented.

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LANDAU DAMPING IN SPACE PLASMAS WITH TWO ELECTRON TEMPERATURE NON-MAXWELLIAN DISTRIBUTION FUNCTIONS

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It is now believed that space plasmas, e.g., planetary magnetospheres and solar wind frequently contain particle components that exhibit high or super thermal energy tails in velocity space. In addition, particle distribution function can have different temperatures, a dense cold population and a hot population. Moreover, in many physical situations when a laser or electron beam is passed through a dense plasma, hot low density electron populations can be generated. Presence of such low density electron distributions can act to increase the magnitude of the wave damping rate. In this paper we employ non-Maxwellian distribution functions such as κ-kappa distribution function and (r,q) distribution function with two electron temperatures to study the Landau damping of electrostatic waves. In the limiting cases when $r = 0$ and $q \rightarrow \infty$, (r,q) distribution function becomes Maxwellian and when $r = 0$ and $q \rightarrow (\kappa+1)$, (r,q) distribution function becomes Kappa distribution function; and Kappa distribution function becomes Maxwellian in the limit when kappa approaches to infinity. The Landau damping is then studied for different values of spectral indices r, q and κ for different temperature and density ratios. The results show that the Landau damping increases significantly when the percentage of high energy particles increases and with the increase in the hot electron population for a particular temperature ratio.

START-UP PHASE OF THE DISCHARGE IN TOKAMAKS

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Start-up of the discharge in a tokamak is defined as the time period between the application of the toroidal electric field in the tokamak vessel and the time, when the steady state phase of the discharge is reached. This phase of the discharge has to be optimized for any tokamak to reduce number of runaway electrons, to save magnetic flux of the tokamak transformer, e.t.c.

The start up of the discharge is divided into three phases, each with different underlying physics:

- Avalanche phase – collisions between electrons and molecules of the working gas dominate, degree of ionization is less than 5%, and trajectories of charged particles are strongly influenced by stray magnetic fields;
- Coulomb phase – collisions between charged particles dominate, degree of ionization increases up to 100% and plasma is Maxwellian with a low electron temperature (<10 eV). Majority of input power goes to ionization and excitation of the working gas;
- Plasma current ramp-up phase –the ramp-up of the current and ohmic heating, equilibrium plasma position in the vessel is kept.

This tutorial lecture is devoted to description of these physical processes as well as to their documentation by means of experimental data from the three tokamaks, which are, or were operational in Prague (COMPASS, CASTOR and GOLEM).

RECENT ADVANCES IN THE STUDY OF LH-GENERATED FAST ELECTRONS IN THE SOL*

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Recent probe measurements **[1, 2]** during lower hybrid (LH) operation in Tore Supra revealed two distinct groups of fast electrons, according to their temporal behavior and radial location. At the LH grill mouth the fast electron signal recorded by a retarding field analyzer (RFA) has a steady DC component. Away from the grill mouth, at all positions reached by the reciprocating probe, the recorded signal is intermittent **[1, 2]**. We have previously advanced the hypothesis **[2, 3]** that the intermittent nature of the fast electrons away from the grill caused by Landau damping of the grill spectrum on dense and hot blobs **[4]** detached at the last closed flux surface (LCFS) around low field side mid-plane. In contrast, the DC signal observed at the grill mouth, is caused by Landau damping of high-$n_{//}$ components of the grill spectrum. Away from the grill mouth, the high-$n_{//}$ spectral components are filtered out, so that only the intermittent signal remains. For access of the spectrum to blobs near the LCFS, sufficiently low-temperature background electrons are needed. Analysis of Tore Supra edge turbulence **[5]** reveals that the fluctuating T_e can fall below 12 eV about 5% of the time. The measured duty cycle **[2]**, i.e. the fraction of time during which fast electron bursts are recorded at some radial position, agrees with that number near the LCFS, and also agrees with the simulated duty cycle using blob velocity and frequency PDFs. Fast electron simulations are carried out for a T_e=10eV and supercritical n_e=3.5x10^{17} m^{-3} background plasma with blob temperature and density assumed equal to time-averaged values measured in Tore Supra shot 39547. A typical estimated value of fast electron parallel power-flow exiting the grill is estimated at about 25 MW/m^2.

MODELLING AND SIMULATION OF REACTING GAS MIXTURES, WITH APPLICATION TO ATMOSPHERIC (RE-)ENTRY FLOWS AND FLOWS IN GROUND TESTING FACILITIES

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During their entry in atmosphere, space (re-)entry vehicles such as manned space transportation vehicles (capsules or winged spacecraft) or planetary probes are exposed to high enthalpy reacting flows and need to be protected against excessive heat fluxes by Thermal Protection Systems. The design of these systems relies on experiments in ground testing facilities and numerical simulations of the flows in these facilities as well as in flight. An accurate modelling of such flows is therefore essential for the proper design of these systems. Modelling and computational issues will be briefly exposed and illustrative applications by the speaker and several PhD graduates will be presented.

MODELING SURFACE KINETICS: ATOMIC RECOMBINATION AND MOLECULE CONVERSION

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This work presents a mesoscopic kinetic model to study atomic recombination and molecule conversion on surfaces. The basis of the model has been developed in [1] for the case of atomic recombination of a single species. The general formalism was then applied to the recombination of N and O atoms on silica-like surfaces. This previous investigation is now extended to study the conversion of molecules, in particular the conversion of NO into NO_2 on a Pyrex surface, as experimentally detected and characterized in [2]. The model takes into account adsorption in physisorption and chemisorption sites, thermal desorption and surface diffusion from the physisorption sites, and recombination both by the Eley-Rideal and the Langmuir-Hinshelwood mechanisms. The dependencies of the recombination probabilities for N and O recombination on the wall temperature and on the pressure are discussed. Finally, the mechanism of surface oxidation of NO is discussed.

[1] V. Guerra, 2007 IEEE Trans. Plasma Sci. 35 1397.
[2] O. Guaitella, M. Hübner, S. Welzel, D. Marinov, J. Röpcke and A. Rousseau, 2010 submitted for publication.

PIC SIMULATIONS OF STRONGLY MAGNETIZED PLASMA DEPOSITION ON TOKAMAK WALLS

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Abstract

In tokamaks, the plasma-surface interactions represent a key-point on the path to success for the controlled fusion. In addition to eventual pollution of the core plasma by heavy ions ripped off from the plasma facing components (PFCs) by high fluxes coming from the plasma, the materials should also be resistant enough to heat flux in the order of 10 MW/m^2 in steady-state, as in the future experimental reactor ITER. In order to withstand the large thermo-mechanical stress generated by those fluxes, ITER's divertor will be castellated, i.e. split into cells separated by small gaps (~1 mm), as it is already the case for most of actual tokamaks' PFCs. The drawback of the castellation is that impurity layers and tritium will accumulate inside those gaps between tiles. Experimental studies have already show significant deposited layers and this could become a real issue for ITER since the operation limit for tritium in the machine is fixed to 350 g. Estimating and controlling particle and power fluxes to the PFCs with such a geometry is therefore of great importance and interest for the fusion community. We present here first two-dimensional, numerical studies of plasma deposition in such complex tile/gap geometry. Due to the large magnetic field in tokamaks the Larmor radii of particles are millimetric, i.e. of the same order than the gap size, and a kinetic approach is therefore more adapted to this problem. For that purpose, we have developed our own code (SPICE2) that is based on a standard particle-in-cell technique, which allows computation of particle trajectories in the gaps. SPICE2 is self-consistent and based on the integration of Poisson's equation and the resolution of the equations of motion. The particle and power deposition profiles with respect to different geometry of tiles and gaps are investigated for various plasma parameters, including ITER ELMs conditions, and presented here.

STATUS OF THE COMPASS TOKAMAK.

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COMPASS is a small tokamak, which was originally operated in UKAEA Culham. Recently, it has started its new operation in the Institute of Plasma Physics (IPP) AS CR in Prague, Czech Republic.

The COMPASS tokamak is able to operate in a clear H-mode in ITER- relevant geometry. COMPASS is equipped with a unique fully configurable set of copper saddle coils for resonant perturbation techniques. ITER-relevant plasma conditions will be achieved by installation of two new neutral beam injection systems (2 x 300 kW), enabling co- and balanced injections. A comprehensive set of diagnostics consisting of e.g. High resolution Thomson scattering system, edge reflectometry, reciprocating probes, beam emission spectroscopy, fast visible cameras and many other focused mainly on the edge plasma is being installed.

Presently, the COMPASS tokamak has been installed and all the main additional systems are in operation. The first plasma has been generated in December 2008 and optimization of the plasma discharge is being performed presently including optimization of the fast feedback system for plasma position control. In this contribution, we summarize the present status of the tokamak, diagnostics and additional systems. We also describe the obtained plasma parameters and plans for plasma performance.

PLASMA POTENTIAL AND ELECTRON ENERGY DISTRIBUTION FUNCTION MEASURED BY LANGMUIR PROBE IN TOKAMAK EDGE PLASMA

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Among the contact methods of plasma diagnostics, the electric probes are the most reliable diagnostic tools allowing one to measure edge plasma parameters with sufficiently high temporal and spatial resolution. Langmuir probes (LP) allow local measurements of the plasma potential, the charged particles density and the electron energy distribution function (EEDF).

The knowledge of the real EEDF is of great importance in understanding the underlying physics of processes occurring at the plasma edge in tokamaks, such as the formation of transport barriers, plasma–wall interactions, and edge plasma turbulence.

In magnetized plasma the electron part of the *IV* characteristic is distorted due to the influence of the magnetic field. For this reason the kinetic theory developed in the non-local approach may be used for the evaluation of the EEDF from the first derivative of the electron current of the *IV* characteristics.

In this work the First derivative probe method will be discussed in details. First results from measurements of the EEDFs in divertor area of new Czech tokamak COMPASS using this technique and the values of the plasma potential, the electron temperatures and densities are presented. It is shown that the EEDFs in some cases are not Maxwellian but can be approximated as bi-Maxwellians with one dominant, low temperature electron population and one minority composed of hotter electrons. The comparison of the results obtained with First derivative probe method as well as the results given by the classic method leads to a satisfactory agreement.

The results presented in this paper demonstrate that the first derivative method allows one to acquire additional plasma parameters using the electron part of the current–voltage characteristics in strongly magnetized tokamak edge plasmas.

This work is in implementation of task P4 of Work Plan 2010 of the Association EURATOM-INRNE.BG in collaboration with the Association EURATOM-IPP.CR, Prague, Czech Republic.

ADVANCED PROBE DIAGNOSTICS FOR MEASUREMENT OF ELECTROMAGNETIC PROPERTIES OF CURRENT FILAMENTARY STRUCTURES IN EDGE PLASMA OF THE TJ-II STELLARATOR AND COMPASS TOKAMAK

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Abstract: Improved understanding the properties of the current filamentary structures in edge plasmas is believed to allow better insight into development and possible control of the Edge localised modes (ELMs) and consequently mitigation of their impact on plasma performance and first wall structures. Several advanced probe diagnostics for characterisation of the filamentary structures in the edge plasma were recently developed. We have focused ourselves to measure electric and magnetic properties of the filaments and electromagnetic features of edge turbulence using combination of 3D coil systems, Hall probes, and Langmuir tips in one complex probe.
On TJ-II, we used probe consisting of two 3D coil sets, two Hall sensors and 4 Langmuir tips. Furthermore, special probe for filamentary measurements for TJ-II is being designed in collaboration with ENEA. This new probe will have three 3D coil sets and 7 Langmuir tips and its design is focused directly on measurement properties of the filamentary structures. Similar probe is designed for the COMPASS tokamak.

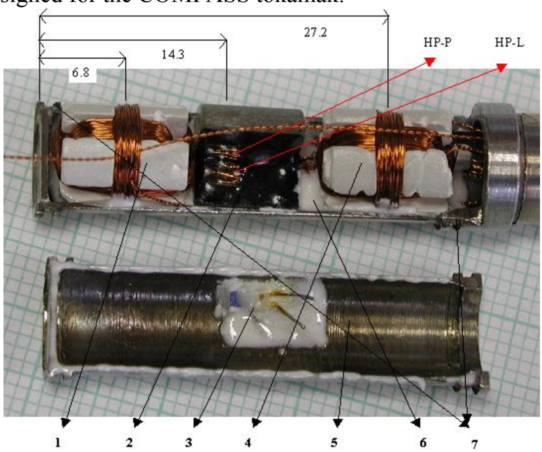

Fig. 1: Photograph of the magnetic part of the combined probe (1: Inner 3D coil set, 2: 2D Hall probe, 3: PT-100 thermo-resistor, 4: Outer 3D coil set, 5. Removable non-magnetic stainless steel lid, 6: Special high vacuum compatible glue, 7: Rift used to accommodate several turns of wire for fixing the removable lid (5) to the rest of the probe's body).

We will present design of these probes and results of first measurements on TJ-II stellarator with the first mentioned probe in this paper.

NEW MODELS FOR PREDICTING PEDESTAL TEMPERATURE AND DENSITY IN ELMY *H*-MODE PLASMA

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Abstract

Models for predicting the temperature and density at the top of the pedestal for type I, II and III ELMy *H*-mode plasma are developed by using an estimation of thermal energy in the pedestal region and energy confinement time. The model for pedestal temperature is in the form of $T_{i,ped} = C_{E,i} \frac{P_{aux}\tau_E}{n_{ped}kV}$; while the model for pedestal density is in the form of $n_{ped} = C_{E,n} \frac{P_{aux}\tau_E}{T_{ped}kV}$. Predictions from these pedestal models are compared with experimental data from the ITPA Pedestal Database version 3.2. Statistical analyses, such as root-mean square errors (RMSE) and offset values, are performed to quantify the predictive capability of the models. Results of findings on temperatures and density will be presented.

Keyword : Pedestal, ELMy *H*-mode plasma

HYDROGEN RETENTION IN VOLUMETRIC CFC SRUCTURES

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Vast information about graphite (CFC) behavior under plasma irradiation is available today. Nevertheless the new details of hydrogen isotope retention in CFC's surface layers and in the bulk under plasma irradiation seem to be of interest.

The paper analysis the results of not published earlier investigation of deuterium and hydrogen retention in the Tore Supra tiles and the data of auxiliary laboratory experiments. The tiles made from CFC N11 were taken from midplane (tile №1) and from upper part of inboard limiter (tile №2). They have been irradiated by Tore Supra plasma from 1995 to 1999. The flux, energy and total fluence of deuterium plasma ions on the midplane tiles were estimated to be $j_i \approx (1\text{-}2)\times10^{19}$ at/m^{2}s, $E_i \approx 100$ eV and $\Phi_i \approx 5\times10^{23}$ at/m^2. The temperature of the tiles reached 500-600°C. More than 20 wall conditioning helium glow discharges were made during this time, resulting in helium ion ($E_i \sim 200$ eV, $j \sim 6\times10^{17}$at/s×m^2) bombardment of the inner wall.

Two samples (10×10×1.5 mm^2) were cut from the tile front surfaces (1-1 and 2-1) and six from the bulk, namely from the depth 2.5-4 mm (1-2 and 2-2), 5-6.5 mm (1-3 and 2-3), 7.5-9mm (1-4 and 2-4). The samples (1-5 and 1-6) and (2-5 and 2-6) represented lateral sides of the tiles.

TDS results showed that deuterium concentration in the surface layers of the front and of the lateral surfaces of both tiles located in the interval 5.7×10^{17} - 2.5×10^{18} at/m^2. The thickness of such a layers was shown to be not higher than 15-20 µm. It is interesting to note that retention of deuterium in the front surface samples was near 30 times higher, than retention in the samples irradiated in the laboratory stand ($j_i=(1\text{-}2)\times10^{19}$ at/m^{2}s, $E_i=100$ eV and $\Phi_i=5\times10^{23}$ at/m^2). The bulk of the tiles collected only ≈5% of deuterium (H:C≈ 9×10^{-9}) .

The shapes of TDS spectra allowed concluding that prevailing fraction of deuterium retained in the near surface layers was accumulated in the traps created by irradiation of some-hundreds-eV particles. They indicated that hydrogen already presented in the tiles before their installation into the tokamak, and deuterium in bulk mainly was trapped in hydrogen traps. Its concentration was rather similar at different depths. Conclusion is made that hydrogen presence facilitated deuterium trapping due to isotope exchange.

The courses of significant increase of deuterium trapping in the tokamak condition in comparison with the laboratory one are analyzed. Among them there is redeposited layers, "technology" hydrogen in the bulk, simultaneous ion and electron irradiation, wide impinging ion energy distribution, high duration of tokamak irradiation, oxygen impurity in the plasma, surface structure decomposition and relief development at the expense of helium irradiation.

Finally the measures allowing significant decease of hydrogen isotope retention in the graphite (CFC) tiles are considered, in particular, preliminary annealing of the tiles, decrease of oxygen concentration in plasma, decrease of splits between tiles, periodical removal of ≈10µm-thick surface layer by ($He+O_2$) rf-discharge and/or use of protecting renewable surface layers.

Estimations shows that fulfillment of listened measures will lead to decrease of hydrogen isotope retention in the near surface layer in several times and to decrease of deuterium concentration in the bulk down to H:C=$(2\text{-}3)\times10^{-9}$. Amount of tritium retained in graphite (CFC) tiles operating in the conditions of ITER divertor (100 m^2) could be kept well below the T-limit.

GLOW DISCHARGE CLEANING OF OXYGEN CONTAMINATED STAINLESS STEEL

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Glow discharge cleaning of stainless steel samples is investigated. Amount of retained oxygen is obtained using TDS analysis. The efficiency of GDC is studied in dependence on irradiating ion energy, flux, fluence, surface temperature and pumping speed. Parameters, peculiarities and mechanisms of O trapping and retention in CFC and SS under irradiation in plasma and of its release by D_2-GDC are presented.

Stainless steel samples (AISI 304) were irradiated in D_2+2%O_2 plasma with 100 and 400 eV/at ions with a flux of $j_i=1\times10^{20}$ at/m^{2}s, and total fluence $\Phi_i=5\times10^{23}$ at/m^2. Then the samples were irradiated in D_2 plasma with the same irradiation parameters and varying fluence. After both irradiations the samples were subjected to TDS analysis without breaking the vacuum.

The sharp decrease of O content in SS occurred at the initial stage of GDC (fig. 1) and reports about its retention in the near surface layer.

The thickness of this layer increased with the increase of ion energy and correlates with depth distribution of implanted D ions. The layer collects remarkable amount of oxygen (8,0x10^{19} at/m^2, O/Me=40-60% when E_i=100 eV, and 8,7x10^{19} at/m^2, O/Me=15-30% when E_i=400 eV/at).

Removal of the surface layer was accompanied by the increase of O trapping in the bulk. Thus, one can conclude that the surface layer had the barrier properties and prevented O penetration into the bulk. Its retention grew and passed through the maximum after some tens of minutes of irradiation. O trapping, more probably, occurred through potential mechanism from the water molecules of residual gas sorbed at the surface.

Decrease of the residual gas pressure during GDC from 1×10^{-3} to 1×10^{-3} Pa led to decrease of O content in the minimum from 9.9×10^{-15} to 7×10^{-15} at/m^2. This result showed that minimum level of O retention was determined by both by O of the barrier layer, and by O penetrating through remaining fraction of the barrier layer and trapped in the bulk during GDC.

Elevation of GDC temperature up to 600 K led to expansion of O-reach layer, to higher extent of SS outgasing at the initial stage of GDC and to increase of O penetration and retention in SS after elimination of the barrier layer. To explain these features one can assume that during GDC the Cr- and O atom diffusion activated along with temperature growth.

Appearance of the maximum of O retention could be the result of decrease of chromium concentration underneath the barrier layer. Formation of near surface barrier layer occurred through transformation of Chromium concentration in the near surface layer. It led to remarkable decrease of Cr concentration in the underneath layer and to its enhanced oxidation during consequence GDC.

POSITRON MOMENTUM CALCULATION OF DEFECTS IN α-Fe AND Fe-Cr CONTAINING HYDROGEN AND HELIUM

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Abstract: Lattice defects containing hydrogen and helium in Fe and Fe-Cr have been studied by positron model calculations using Density Functional Theory [DFT] in its local density approximation [LDA] implementation. It was found that the value of positron lifetime for perfect Fe lattice is 102 ps. and for mono vacancy is 177 ps. which corresponds to the experimental values. The calculated results of coincidence Doppler broadening [CDB] for perfect Fe lattice are shown in Figure 1. The calculated values of positron lifetime for Fe-2.5% wt Cr is 134 ps., for Fe-5% wt Cr is 147 ps., for Fe-7% Cr is 142 ps. and for Fe-9% Cr is 132 ps, respectively. A correlation between the positron lifetime and H and He atom concentration has been established. The model calculations for positron lifetime and CDB for Fe-Cr containing 1, 2 and 3 vacations in the presence of different numbers of hydrogen and helium atoms will be presented.

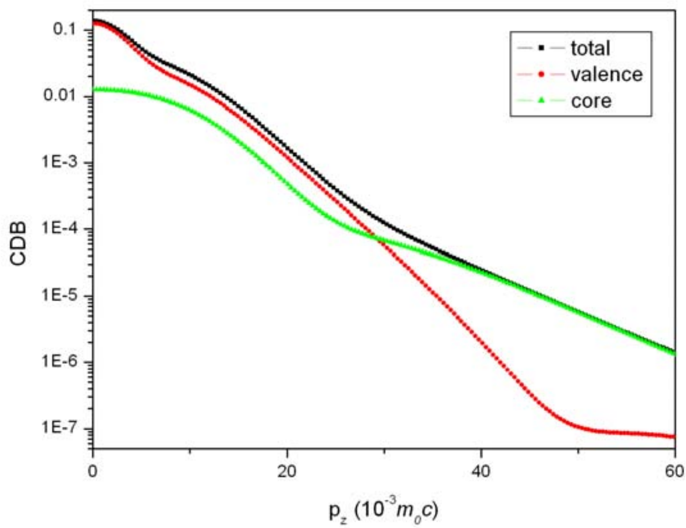

Figure 1. Coincidence Doppler broadening as a function of electron momentum distribution for perfect Fe lattice.

DEFECT ANNEALING IN PURE IRON AND PALADIUM MEASURED BY COINCIDENCE DOPPLER BROADENING SPECTROSCOPY

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Recent years have seen a renewed interest in the technique of Coincidence Doppler Broadening Spectroscopy (CDBS) in which one-dimensional electronic momenta in materials are studied by means of the energies of the two gamma-rays emitted in the process of positron annihilation. Advantages of CDBS over conventional positron Doppler spectroscopy are its 40% improved energy resolution and its significantly reduced background. New CDBS system has been setup and tested with a reference sample of annealed aluminum. The electron momenta distribution (EMD) in pure Fe and pure Pd were measured by CDBS before and after annealing and compared to the EMD computed by computer codes for model calculations of the positron wave function in these materials. The quality of the sample annealing was controlled by measuring the positron annihilation lifetimes. Fe and Pd samples have been chosen to check the capability of the calculation models to describe the defect annealing.

THE SPECTRA OF HYDROGEN THERMAL DESORPTION FROM GRAPHITES AND THEIR INTERRELATIONS WITH IMPLANTATION AND RETENTION CONDITIONS

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Based on the analysis of data reported from different authors one can conclude that the position of a thermo desorption peak on the spectrum and irradiation conditions, which in turn determine the degree of irradiation damage of the sample graphite and relations of trapping and retention, are connected. Though, all the data existing cannot be utilized directly since the ramp rates differ in different works (from 0,08 K/s up to 70 K/s). As it is known [1], this leads to a shift of a peak maximum on the TDS spectrum.

The ramp speed equaled 5 K/s was taken as a base one for further analysis, because a significant part of studies is performed using this value. Data from work [1] and our measurements were used to plot the peak shift relative to peak position with ramp rate 5 K/s. Than analysis of recalculated values of the peak maxima was performed.

One can see that the irradiation of graphite with thermal energies leads to the desorption in the 975-1083 and 1375-1483 ranges [2-4]. Graphite irradiation with atoms having thermal energies doesn't destroy its structure. Authors of these studies suppose that trapping in such traps can be associated with the formation of C-H bonds with carbon atoms situated on the border dislocations. It was shown in studies [2,4] that the desorption is of the second order and the limiting phase is hydrogen release from 2,4 and 4,1 eV traps. In case of ion beam bombardment of a graphite surface, when fluencies exceed saturation amount of stopping zone and most part of hydrogen trapped is in the stopping zone, peaks in the range of 900-1000 K occur on the TDS spectra, and also hydrogen desorption in the 1100-1400 range, as in the case of hydrogen atoms irradiation, is observed. One can suppose, that 900-100 peak corresponds to hydrogen being trapped into the traps formed by ion bombardment, and 1100-1400 K desorption corresponds to traps from the undamaged bulk beneath the stopping zone.

Besides the high temperature peak in the range of 1020-1185 K, peaks, characteristic for ion beam irradiation occur during plasma irradiation with energies >200 eV, and shoulders in the ranges 700-800 and 500-600 K are formed. 700-800 K peak becomes the main one in case of ion energies below 200 eV or in case of electron irradiation, and slight shoulders and peaks are observed in the ranges of 500-600 K and >1200K. Low temperature peaks are formed when hydrogen is released from the traps created with the potential energy of incident ions and electrons with the graphite and filled as with the bombarding ions as with the hydrogen sorbed on the surface. The study performed will be clarified and appended and could be useful for the analysis of hydrogen trapping and retention in graphite.

LITERATURE

[1] K. Ashida, K. Ichimura, M. Matsuyama, et al. J. Nucl. Mater. 128-129 (1984) 792.
[2] E. Denisov, T. Kompaniets, Zhurnal Tekhnicheskoi Fiziki,71. (2).(2001)111.
[3] Z. Vakar, E. Denisov, T.Kompaniets, et al. . Zhurnal Tekhnicheskoi Fiziki.71(6)2001.133.
[4] V. Philipps, E. Vietzke, M. Erdweg and K.Flaskamp. J. Nucl. Mater. 145-147 (1987) 292.

DEUTERIUM TRAPPING IN GRAPHITE AND CARBON FILMS GROWING UNDER IRRADIATION BY DEUTERIUM PLASMA

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Tritium inventory in reactor materials is one of the key issues for ITER and future fusion reactors. Carbon materials are still planned to be used in ITER; and tritium accumulation in the bulk graphites as well as in C:T films re-deposited after erosion of carbon materials by plasma can be serious channels of tritium inventory. This work was motivated by the investigation of hydrogen trapping in graphite and co-deposition carbon films.

A planar magnetron discharge machine with the target assembly was used for investigation of deuterium trapping in various materials and re-deposited films. Samples were installed both on the cathode and outside the cathode either under ground potential or under a bias. Samples on the cathode were exposed to deuterium plasma with various fluxes (from 1.5×10^{20} ion/m^{2}s· to 1.5×10^{20} ion/ m^{2}s·) and fluences (from 5×10^{23} ion/m^2 to 5×10^{24} ion/m^2). High Z materials (Mo) and low Z materials (C) were used as a mask that covers the target.

Two regimes were identified: first one is characterized by dominant sputtering of the samples, the second one exhibited dominant redeposition of material from the mask on samples. SEM study of irradiated samples revealed the surface topography change caused by the ion bombardment. This change tends to flatten the surface roughness and open the initially hidden bulk pores at high (>5×10^{24} ion/m^2) fluences applied. For lower (<5×10^{23} ion/m^2) fluences the initial roughness plays a significant role in D retention.

All samples were analysed by thermal desorption spectroscopy (TDS) after exposure. Deuterium inventory in hydrocarbon films formed in the deposition regime greatly exceeded the inventory in graphite in the regime of sputtering. Trapping in graphite depends on the degree of mechanical treatment of the surface: it is higher for the surface with the developed relief. TDS spectra are in the range of 400-1500 K. Desorption from hydrocarbon films occurs in the same temperature range and have similar positions of peaks. Electron microscopy analysis of irradiated surfaces demonstrated strong modification in both regimes. It is concluded that deuterium trapping centers in graphite, which is modified by plasma ions, and those in films, which grow under plasma ion irradiation, are similar.

PIC SIMULATIONS FOR TEXTOR TEST LIMITER EXPERIMENTS WITH SHAPED AND NON-SHAPED GAPS

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Abstract:

This paper presents Particle-In-Cell simulations of the plasma behavior in the vicinity of gaps in castellated plasma-facing components. The particular point of interest were gaps in the test limiter of TEXTOR tokamak, which is a plasma-facing component designed for studies of impurity transport and fuel retention, mainly via hydrocarbon layer formation. The castellated limiter tiles have been analysed using the post-mortem techniques and impurity transport modelling was done using the 3D-GAPS code. In order to improve the agreement between modeling and experiment, realistic plasma particle flux distribution needs to be included in 3D-GAPS. For this purpose, a series of PIC simulations for varying plasma conditions was performed by using the SPICE2 code. Plasma behavior inside the gaps is discussed.

ON THE PLASMA POTENTIAL EVALUATION IN LANGMUIR PROBE MEASUREMENTS IN TOKAMAK EDGE PLASMA

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It is known [1] that the EEDF in tokamak edge plasma is not Maxwellian but can be approximated as bi-Maxwellians with one dominant, low temperature electron population and one minority composed of hotter electrons. In this case the interpretation of the current voltage (IV) characteristic measured by Langmuir probe is problematic in regard of evaluating the plasma potential [2].

Model calculations using the extended Druyvesteyn formula [1] allow finding connection between Floating potential of the IV and Plasma potential in strongly magnetized tokamak edge plasma.

The Plasma potential results obtained in tokamak edge plasma (CASTOR and COMPASS tokamaks) using First derivative probe method [1] and model calculations show a satisfactory agreement.

This research is in implementation of task P4 of Work Plan 2010 of the Association EURATOM-INRNE.BG in collaboration with the Association EURATOM-IPP.CR, Prague, Czech Republic.

References:

[1] Tsv K Popov **et al** 2009 **Plasma Phys. Control. Fusion 51** 065014
[2] Stangeby P C 1995 *Plasma Phys. Control Fusion* **37** 1031-37

LANGMUIR PROBE EEDF EVALUATION IN A_r MAGNETIZED PLASMA

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Among the contact methods of plasma diagnostics, the electric probes are the most reliable diagnostic tools allowing one to measure edge plasma parameters with a sufficiently high temporal and spatial resolution. In non-magnetized low-density plasmas LPs allow local measurements of the plasma potential, the charged particles density and the electron energy distribution functions, $f(\varepsilon)$ (EEDF).

In magnetized plasma, the interpretation of the electron part of current-voltage (IV) characteristics above the floating potential, U_{fl}, still remains difficult because the electron part of the IV characteristics is distorted due to the influence of the magnetic field.

In this work we report measurements of the EEDF in low pressure linear magnetized argon discharge plasma with magnetic field in the range of 70 – 790 G. The main part of the plasma device consists of 1.5 meter long stainless steel tube with 17 cm inner diameter. The plasma was produced with discharge from hot filament cathodes. Axial magnetic field is created with a solenoid. The maximum magnetic field can go up to 0.4 T. although the measurements were performed at lower magnetic fields.

It was shown that at low magnetic fields (70-350 G) to evaluate the EEDF the extended second derivative probe method has to be used, since at magnetic fields above 350 G - the first derivative method gives correct values.

The results presented were obtained in implementation of task P4 of Work Plan 2010 of the Association EURATOM/INRNE.BG in collaboration with the University of Ljubljana, Faculty of electrical engineering and the Jožef Stefan Institute, Ljubljana, Slovenia.

NEW LANGMUIR PROBE CIRCUITS FOR IV MEASUREMENTS IN COMPASS TOKAMAK EDGE PLASMA

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The presented device is second generation amplifier, made by Tsv. Popov's team (Mladen Mitov, Ana Bankova, etc), for current voltage (IV) characteristics measurements in COMPASS tokamak (IPP, CR) edge plasma. On the previous version the signal was measured fully differential. That's why, the common mode signal was pretty high (~100V). Even though, the amplifiers had high common mode rejection ratio (~77dB) the signals on the output of the amplifiers caused by the Ion saturation current and the signals caused by the common mode signal were comparable. Because of this problem we went to common ground measuring. The common ground measuring has the advantage of absence of common mode signal, and the disadvantage of necessity of power amplifier per each channel.

The new boards also include active low pass filters which smoothes the signal before it's been recorded by the DAQ. Like this, the signal is less noisy and the data processing is much easier. Also we have designed a microcontroller driven, custom waveform generator with resolution of 1Ms/s. The power supply is linear and uses a transformer. We avoided the use of switching power supply, because of the noises that it generates.

Examples of measurements with divertor probes in COMPASS tokamak of the IV characteristics and further evaluating of EEDF will be presented.

This research is in implementation of task P4 of Work Plan 2010 of the Association EURATOM-INRNE.BG in collaboration with the Association EURATOM-IPP.CR, Prague, Czech Republic.

COLD EMISSION OF THE NEGATIVE CHARGED PARTICLES FROM PORES SURFACES

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When plasma interacts with the first wall, the last is under bombardment by ions. The wall emits electrons in plasma due to ion-electron emission and due to temperature thermo electron emission. It was known that plasma potential is higher that potential of the wall due to elections escaping from plasma. This potential stands in the length about 10 Debye radia. So, the electric field strength in the sheath of ITER (with concentration $4{,}1\cdot10^{20}m^{-3}$ and electron temperature 170 eV) near PFC surface is expected to approach $3{,}6\cdot10^{7}$V/m. In the case of a sharp relief, auto electron emission can be expected due to strengthening of the electric field near field. Besides, emission can be stimulated by processes in pores on the surface. It was previously shown that even at the electric field strength of 10^{5}-10^{6}V/m current densities from a porous cathode can reach the value of about 1 A/m^{2} [1]. In principal, such sort of cold emission can influence sheath potential and change PWI conditions. Field emission of negatively charged ions can also be an additional source of impurities in plasma.

The special experiment with well polished sample with artificial pores was carried out for testing of the sources of elections at electrical field strength of 10^{6}-10^{7}V/m. The sample with artificial made pores was placed in the special magnetic microscope [2]. It consist of the strong permanent magnet with magnetic field lines perpendicular to the surface of the sample. The emitted electrons wind around this lines and goes along its to the screen with a phosphor. So, one can see the picture of the emission centres on the screen. First experiments have shown that sources of negative particle can be identificated as pores, microdust on the surface and contact area between conductor and dielectric films on the surface.

[1] V. A. Kurnaev, N.V.Tatarinova, J.Nucl.Mater. 220-222 (1995) p.939-942

[2] A. I. Markin, E. P. Poluljah, V. E. Cherkovets, Instruments and Experimental Techniques № 5 (1999), p. 108-113;

MEASUREMENTS OF THE BASIC CHARACTERISTICS OF THE DENSE PLASMA FOCUS DEVICE AT THE UNIVERSITY OF SOFIA

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In the Faculty of Physics at the University of Sofia a Mather's type dense plasma focus device (DPF) is constructed. In the experiments with this device it is possible to obtain the quantitative results of the typical processes in a small DPF.
The capacitor bank has capacitance of 20 μF, with the maximal voltage of 40 kV. The insulator is molten quartz, the main switch is a vacuum spark gap. A procedure for optimizing the discharge conditions was carried out, changing the charging voltage and the gas pressure. So far the experiments were conducted in air. Thus the voltage operating range is 15 – 18 kV, and the nominal pressure is in the range 1.3 – 1.7 mBar.
We are monitoring the discharge current, the current derivative, the soft X-ray and the hard X-ray emission from the plasma. The data, received by the diagnostic tools in the first several hundred shots fired so far, reveal the typical peculiarities known from the literature for the devices of this energy range (3- 5 kJ) : The oscilloscope pictures give the moment of the initial breakdown of the gas, followed in a few microseconds by the occurrence of a pinch. A correlation between the observed one or more peaks of soft and hard X-rays and the peculiarities of the dI/dt signal is established, the latter corresponding to the same number of pinches with the same mutual distance in time. More than one pinch is a situation typical of a DPF, operating with heavy gasses such as nitrogen or argon. On the other hand, when working with hydrogen (including deuterium and tritium) or helium, as a rule only a single pinch takes place [1]. Adding a brass solid end to the hollow anode resulted in increased hard X-ray yield. It also appeared that the soft X-ray peaks are a little delayed (0.2 - 0.3 μs) from the relevant pinch moments on the dI/dt graph, and the hard X-ray peaks being delayed even more (0.3 - 0.4 μs). We observe some fluctuation from shot to shot of the peak positions in time.
From the signals of the mounted 4 PIN BPX 65 photo diodes we achieve useful information about the soft X-ray emission of the pinch plasma. In front of each photodiode metal filters are placed (10, 20 and 30 μm aluminum and 0.5 mm lead respectively), transmitting only radiation with energy above certain values. These signals are in direct accordance with the number of contractions and with the soft X-ray yield. They depend also on the operating pressure and voltage [2].
With the thermo luminescent dosimeters we found that the full X-ray dose in the stainless steel chamber of our DPF is in the order of a few tenths of 1 Sv, while outside is close to the natural ionization (gamma) background.

References

1.Alan Bernard et al "Scientific status of plasma focus research", Journal of Moscow Phys. Soc., **8** (1998) 93-170.
2. Sing Lee, Paul Lee, Guikin Zhang, Xianping Feng, Vladimir A. Gribkov,…,"High Rep Rate High Performance Plasma Focus as a Powerful Radiation Source", Transactions of plasma science, **26** №4, Aug. 1998.

DEVELOPMENT OF A TECHNIQUE FOR DETECTION OF LOW DENSITIES OF SPUTTERD TUNGSTEN ATOMS

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The main objective of this study is the development of a technique and the respective setup for distant determination of low density of sputtered W atoms by using spectroscopy methods, ncluding absorption, emission and fluorescence. Additional results can be expected on the transport properties of the tungsten atoms and ions in rare gases.

In 2008 the first results from absorption experiments were obtained using a multi-pass (MP) absorption system in a glass discharge cell with external mirrors. Due to the low cell transmittance in the UV region only a 2-pass configuration was used. An estimation of the diffusion coefficient of the sputtered tungsten atoms in argon was obtained [1]. A disadvantage of the setup is that the mirrors of the multi-pass cell were mounted outside the absorption cell and there were significant losses of signal due to reflections by the windows. To overcome this problem a new stainless steel vacuum vessel was constructed. It is equipped with a number of ports with quartz windows, which allow a variety of possibilities for excitation and observation (absorption and fluorescence (in parallel and perpendicularly to the excitation direction)). The vessel is equipped with an inner supporting frame which caries the mirrors of the MP cell and the hollow cathode assembly used for W sputtering. The alignment of the mirrors can be accomplished outside the vessel and does not require further adjustment when the frame is placed inside the vessel. The hollow cathode was chosen to be 200 mm long with 20 mm inner diameter. It consists of an outer copper tube wherein a 1 mm thick tungsten foil is rolled. Our experience so far shows that the remaining distance of 100 mm to each of the cell mirrors should be enough to protect the mirrors from tungsten deposits. For registration of the optical emission from the source (Hamamatsu hollow cathode lamp) and the absorption tube, an 1.5 m Jobin Yvon spectrometer is used.

In this work results from measurements of tungsten emission spectra and absorption measurements will be presented.

[1] A. Blagoev et al., Journal of Physics: Conference Series, **207** (2010) paper 012017

EXPERIMENTAL RESULTS OF BREAKDOWN IN "DENA" PLASMA FOCUS DEVICE

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Abstract:
In spite of the intense research activities on Plasma Focus devices in the last 5 decades, the physics of the initial breakdown and surface discharge phase in them has not been realized completely . In this paper we have analyzed the surface discharge & initial breakdown phase in Filippov-type Plasma Focus device "Dena" (90 kJ, 25 kV) on the base of the current & current derivative measured signals by using Argon , Neon and Krypton as working gases in different discharge voltages and gas pressures, and the effects of working conditions (atomic weight, discharge voltage and gas pressure) on the breakdown & surface discharge phase have expressed**.** Also, on the base of these results, we have investigated about relation of this phase with final pinch phase.

COMPARISON THE RESULTS OF NUMERICAL SIMULATION AND EXPERIMENTAL RESULTS FOR AMIRKABIR PLASMA FOCUS FACILITY

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Abstract

In this paper the results of the numerical simulation for Amirkabir Mather-type Plasma Focus Facility (16 kV, 36μF and 115 nH) in several experiments with Argon as working gas at different applied voltages and gas pressures have been presented and compared with the experimental results. Two different models have been used for simulation: five-phase model of Lee and lumped parameter model of Gonzalez. It is seen that the results (optimum pressures and current signals) of the Lee model at different working conditions show better agreement than Lumped parameter model with experimental values.

MEASURMENT AND ANALYSIS OF THE RADIATION LOSSES IN DAMAVAND TOKAMAK

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Abstract:
Radiation losses play an important role on reaching the break-even conditions in Tokamaks. In this paper the results measuring by a bolometer in Damavand Tokamak, have been presented & analyzed. It must be noted that a bolometer only gives a spatial canal of information and the recorded signals by it relates to radiated power from a finite part in the Plasma of Tokamak. With respect to that in our experiments the determination and control of Plasma position was impossible, we could not certainly conclude about the amount of radiation losses and we only could investigate about the variation of them in general form.
By a new control system which installed for 6 months ago in DAMAVAND, we can control and change the position of the Plasma with high accuracy, so it is possible to bring the dense Plasma region in front of the bolometer window and record the main part of the radiation losses. Also, it is estimated that the accuracy of the results would be improved about 10 times.

GUIDING OF LASER BEAM IN NON UNIFORM PLASMA CHANNEL WITH HIGHER ORDER NONLINEARITY

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The effect of higher order nonlinearity on the guiding of the laser beam in a plasma channel formed by short ionizing laser pulse is investigated in this paper. When a delayed pulse propagates through this channel diffraction, refraction and self-phase modulation phenomena results which are not balanced resulting in increase/decrease in beam width. Parameters like beam width and longitudinal phase delay of cylindrical laser beam are also studied. These are studied using the direct Variational Technique. Guiding up to several Rayleigh length has been observed. The results of the analysis are useful in understanding physics issues of ICF involved in laser-plasma interactions.

Key words: Guiding, Rayleigh length, plasma-channel, nonlinear-medium

MICROWAVE PLASMA TORCHES USED FOR HYDROGEN PRODUCTION

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A microwave plasma torch operating at 2.45 GHz and atmospheric pressure has been used to create a plasma environment to decompose ethanol/methanol. To this end, plasma in a gas mixture of argon and ethanol/methanol, with or without water, has been created using a surfaguide launcher and microwave generator delivering a power in the range 200 - 2.0 kW. The discharge takes place in a quartz tube (1.5 cm inner and 1.8 cm outer diameters, respectively) open at one end. The total gas flow is 1000 sccm. The argon gas used had a purity of 99.999%. Pure ethanol/methanol is introduced into the discharge by bubbling of Ar through the alcohol at room temperature.
Mass, FT-IR and optical emission spectrometry have been applied as diagnostic tools. Mass and FT-IR spectroscopy have been used to detect the molecular hydrogen produced by ethanol/methanol decomposition in the argon plasma environment as well as other molecules such as H_2O, CO, CO_2 etc. The influence of the fraction of Ar "bubbling flow" through the liquid ethanol/methanol on the H_2 and CO partial pressures has been investigated.
The optical emission spectrum in the range 250 - 700 nm has also been detected. There is an increase of the OH(A-X) band intensity when the percentage of methanol in the mixture increases. The emission of carbon atoms in the near UV range (240-300nm) exhibits a significant increase with the amount of methanol in the mixture.

EXPERIMENTAL SIMULATION OF TITAN'S ATMOSPHERE: OPTICAL EMISSION SPECTROSCOPY OF A PLASMA DISCHARGE OF $Ar/N_2/CH_4$ TERNARY MIXTURE

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Abstract.

A low-pressure DC plasma discharge sustained in a 85.0%N_2-12.0%Ar- 3.0%CH_4, 82.3%N_2-13.7%Ar- 4.0%CH_4, 79.6%N_2-15.4%Ar- 5%CH_4 and 77.0%N_2-17.0%Ar- 6.0%CH_4 ternary mixtures are studied. These plasmas were generated in the total pressure range of 0.5 to 10.0 Torr, power of 7 W and 50 l/min flow rate gases. The diagnostic has been made by optical emission spectroscopy (OES) using a spectrometer. The principal species observed were: at 315.93, 337.13, 375.54, 399.84 and 405.94 nm for N_2 ($C^3\Pi_u \rightarrow B^3\Pi_g$); at 354.89, 358.21, 376.16, 391.44 and 427.81 nm for N_2^+($B^2\Sigma_u^+ \rightarrow X^2\Sigma_g^+$); at 381.06 nm for CH^+($A^1\Pi \rightarrow X^1\Sigma^+$); at 392.08 nm for CN($B^2\Sigma \rightarrow X^2\Sigma$); at 428.15 nm and CN($B^2\Sigma \rightarrow X^2\Sigma$); at 436.52, 592.34, 653.40, 667.73 and 708.32 nm for C_2($A^3\Pi_g \rightarrow X'^3\Pi_u$); at 392.59 nm for C_3($^1\Pi_u \rightarrow {}^1\Sigma_g^+$); at 486.14 nm for H_β; at 486.13 and 656.27 nm for H_α; at 739.23, 751.47, 763.51, 772.42, 794.82 and 811.53 nm for Ar. We present the behavior of the bands and lines intensities as a function of the pressure and concentration of Ar, N_2 and CH_4 gases. Also, we display more quantitatively the ratios of intensities of N^+_2 (391.44 nm), CN (392.08 nm), and H (486.13 nm) to that of the N_2 (337.13 nm) as function of pressure. The ratios show an almost constant behavior as a function of the pressure being the CH/N_2 ratio highest and H/N_2 ratio the lowest one. The variations of excited species at different pressures may change the subsequent chemical reactions in the gas phase significantly. The present results suggest that the ion–molecule and molecule-molecule reactions in the gas phase are likely to play a dominant role in the present pressures.

WIDEBAND HIGH VOLTAGE HIGH CURRENT PROBE DRIVER

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Abstract: Wideband high current high voltage driver amplifier is presented, intended for probe plasma diagnostics. Currents up to 3A can be drawn by a probe, representing effectively a capacitive load to the amplifier. The high speed diagnostics requirements are met by a wideband amplifier circuit enabling up to +/- 150V with a bandwidth of 100kHz at a capacitive probe load.

SPATIALLY-RESOLVED INVESTIGATION OF HYDROGEN DISCHARGE SUSTAINED BY PROPAGATING SURFACE WAVES

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An experimental investigation on the spatial structure of a long (~ 1 m) H_2 plasma column generated and sustained by a propagating surface wave (SW) is presented. The discharge is created using a surfatron-based setup coupled to a 500 MHz generator, whose output was varied from 65 to 100 W, and takes place inside a Pyrex tube with internal and external radii of 2.25 and 2.5 cm, respectively. Plasma-emitted radiation is collected perpendicularly to the discharge by an optical system including a custom imaging optical fibre and coupled to a 1250 mm focal length spectrometer equipped with a nitrogen cooled CCD camera. Abel inversion has been applied to derive radially resolved profiles of Balmer emissions, which exhibit a bi-Gaussian structure (see figure). This could indicate the existence of two groups of atoms, i.e., a “hot” group corresponding to the central peak and a “super hot” one corresponding to the broadened part. The measured profiles change significantly along the radius. The broader base expands towards the wall, indicating that even hotter H atoms are present in that region. Phase and amplitude measurements using a vector voltmeter were carried out in order to obtain the surface wave dispersion characteristics, i.e., wave number and attenuation coefficient. Comparison with the theoretical dispersion shows that the electron density ranges from about 5×10^{11} cm^{-3}, at the beginning of the column, to about 5×10^{9} cm^{-3} at the discharge end.

UNDERWATER CAPILLARY DISCHARGE WITH SYMMETRICAL HOLE: DIAGNOSTICS AND PUMP EFFECT

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Capillary discharge investigated by this work was created in the reactor using positive half-cycle of AC high voltage up to 2 kV. Electric field created between two electrodes which were separated by the dielectric ceramic barrier with a symmetrical cylindrical hole (diameter of 1 mm, length of 5 mm) in it [1]. When voltage reached the value sufficient for liquid breakdown, the discharge appeared initially in bubbles of evaporated solution in the hole vicinity and spread further into the liquid volume. After the rise of discharge, two kinds of plasma channels (streamers) propagated towards electrodes from the pin-hole: longer positive streamers on the side with the cathode (analogically as in the positive corona discharge) and shorter negative streamers (like negative corona discharge). These streamer kinds differed especially in the energy dissipation originating from different electron velocities in plasma channels due to electron collisions with positive particles accelerating or decelerating electron avalanches and it gave rise of a significant pump effect [2].
This work presents our research focused on the pump effect using the symmetrical geometry of the capillary. Parameters such as initial solution conductivity or input power on this effect as well as diagnostics by optical emission spectroscopy and electrics characteristics have been investigated.

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References
[1] A. Nikiforov, Ch. Leys, *Plasma Sources Sci. Technol.* **16**, (2007) 273-280
[2] F. De Baerdemaeker, M. Šimek, Ch. Leys, W. Vestraete, *Plasma Chem Plasma Process.* **27** (2007) 473-485

INFLUENCE OF ELECTRODE CONFIGURATION ON DC DIAPHRAGM DISCHARGE BREAKDOWN IN ELECTROLYTE SOLUTION

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The work deals with electrical discharge breakdown in water solutions of selected electrolyte (NaBr, initial solution conductivity of 350 $\mu S \cdot cm^{-1}$) with focus on changes in the diaphragm configuration. The batch reactor was divided into two electrode spaces by the dielectric barrier and non-pulsed DC voltage up to 2 kV was used for the discharge creation. The discharge appeared in a pin-hole (initial diameter of 0.4 mm) in the dielectric diaphragm (PET, thickness of 0.25 mm). Planar electrodes made of stainless steel or platinum were installed on each side of the diaphragm. The distance between each electrode and the dielectric barrier was shifted in order to determine its influence on the discharge ignition. The electrode distance was changed either symmetrically with respect to the central diaphragm or only one electrode was moved while the other one remained at the fixed distance.
Oscilloscope Tektronix TDS 1012B operating at 100 MHz with high voltage probe Tektronix P6015A were used to obtain time resolved characteristics of discharge voltage and current with focus on the breakdown moment. Mean values of breakdown parameters (voltage, current, power and resistance) were estimated and subsequently, VA characteristics were evaluated for each experiment. Obtained results were compared with respect to the electrode configuration (distance from the dielectric diaphragm, electrode polarity and material).
Discharge ignition moment in the pin-hole was significantly dependent on the electrode distance. Breakdown voltage increased with the increasing electrode distance as well as time resolved characteristics changed its evaluation with the enhanced distance. Moreover, substantial formation of bubbles in the pin-hole was observed and this phenomenon also influenced the evaluation of studied electric characteristics.

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INVESTIGATION OF THE NBI HEATED PLASMA ON THE GLOBUS-M TOKAMAK WITH THE USE OF THOMSON SCATTERING DIAGNOSTICS

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Electron component spatial distribution dynamics on the Globus-M spherical tokamak was investigated during the NBI heating. The key tool of this research was the upgraded Thomson scattering (TS) diagnostics with variable interval between probing pulses (totally 20) and scattering points placed along the major plasma radius from the inner to the outer plasma border (totally 10). Such arrangement helped to study the dynamics of the full electron temperature and density profiles with required temporal resolution during a single tokamak discharge. The details of the TS system upgrade are discussed. The complete set of the Globus-M diagnostics was also used to provide data for modeling and transport analysis.

Simulation of electron transport in the L and ***H***-mode discharges were carried out using the automated system for transport analysis (ASTRA) for the dischargers with relative low ($0.5x10^{20}$ m^{-3}) and high ($1x10^{20}$ m^{-3}) densities. The transport model consist of continuity equation for plasma density, ion and electron energy balance equations and an equation for the poloidal flux solved together with the Grad-Shafranov equation in the real geometry of spherical tokamak Globus-M. The boundary value of poloidal flux comes from the measured total plasma current, and for conductivity calculated by the neoclassical code NCLASS. Special attention is paid to the effective anomalous transport coefficients.

MODIFIED BY AIR PLASMA POLYMER TRACK MEMBRANES AS DRAINAGE MATERIAL FOR ANTIGLAUCOMATOUS OPERATIONS

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Interest in the treatment of refractory glaucoma by implantation of drainages on the basis of various materials is getting enormous due to a high degree incidence of this pathology and its serious complications. The refractory glaucoma accounts about 40% of all glaucoma pathology. Unsuccessful antiglaucomatous operations result, as a rule, from proliferation of connective tissue and obstruction of surgically formed outflow tracts. Therefore, search for new drainage materials for antiglaucomatous operations is getting quite an urgent problem. In this paper we report on experience of using the polymer track membranes with a nanostructured surface as a drainage material for antiglaucomatous operations. For experiments poly(ethylene terephthalate) and polycarbonate track membranes with a thickness of 10.0 μm and an effective pore diameter of 400 nm were used (pore density of 5×10^{7} cm^{-2}). By preliminary tests it has been found that the membranes of this type are stable to biodestruction and can remain in the intrascleral space for several years. For nanostructuring the membrane surface, a treatment by air plasma was applied. For this purpose a plasma-chemical reactor using a RF-discharge (13.56 MHz) was used. As it was shown, with the help of such a treatment one can reach increase in the contents of carboxyl groups in the membrane surface layer, development of roughness of the membrane surface as well as increase of the drainage porosity.

Experimental research of the drainage material was conducted by its implanting in the anterior chamber and sclera layers of the rabbits and patients eyes. The clinical analyses after glaucoma surgical treatment have been performed during six months after the operation. It has been found that no signs of either inflammation, cell infiltration, neovascularization of cornea and iris or anterior and posterior synechia have been found in eyes during six months after operation. Histological research data demonstrate that the reaction of the inflammatory cells to drainage is minimal. The implant does not resolve and keeps its porous structure during up to six months. Fibrosis capsule around the drainage is not exposed. There was not a single case of reaction to drainage. After operations with nanostructured track membranes in all cases filtering blebs were split and plane. In all cases stable hypotensive result was achieved. Thus, the morphological and clinical studies of nanostructured track membranes as drainage clearly demonstrate its compatibility with eye tissues. Moreover, a new drainage has a good lasting hypotensive effect and can be used as operation for refractory glaucoma surgery.

ATMOSPHERIC PRESSURE PLASMA SOURCE USED FOR MEDICAL APPLICATIONS

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In the last period of time novel experiments using atmospheric pressure plasma are applied in treatment of living cells, tissues, and organs. These create a new field at the intersection of plasma science and technology with biology and medicine, mainly known as Plasma Medicine. This field has many technological challenges and brings to the forefront many fundamental questions regarding the mechanisms of interaction between living organisms and plasma. Nowadays major interest concerns the plasma jet discharges at atmospheric pressure. The variety of the atmospheric pressure plasma jet can be classified using parameters such as working gas, repetition frequency of the applied voltage pulse and the electrodes configuration. Atmospheric pressure plasma jet is studied nowadays in interaction with different types of natural materials, such as biopolymers or bio-composites and even micro-organisms or living tissue, due to its simplicity and versatility. An important parameter for this type of discharges is the rotational temperature that is equivalent, in many cases, with the gas temperature. Sometimes even a few tens of degrees difference in gas temperature can play a substantial role in modification of biological substrates. This is particularly important when various plasmas interfere with biochemical processes such as enzyme kinetics, blood coagulation or wound healing.

In this study, an atmospheric pressure plasma jet in helium with impurities was generated by cylindrical dielectric barrier discharge configuration, which was used in experiments on plasma – tissue interaction. The emission spectra of excited species from the discharge were registered and used for measuring specific plasma parameters such as rotational temperature, which was calculated from the nitrogen molecular ion emission band at 391.4 nm. Moreover, using an intensified charge-coupled device (ICCD) camera evolution of the plasma jet between the electrodes was studied and high speed plasma structures (bullet like) were found. Based on the experimental results obtained, by monitoring the plasma active species correlations can be made with the values of the oxidative stress in the tissue, measured with biochemical techniques.

The optical emission spectroscopy is a quick and powerful technique for monitoring of the active species presented in the plasma. We also found an increased value of the oxidative stress induced inside of the plasma treated living tissue, witch can be related to the presence of plasma active species, such as O and OH radicals. Moreover, the time needed for the regeneration period of the wounded tissue is tow times lower for the plasma treated one than in the case of the natural healing.

ION ENERGY DISTRIBUTION IN THERMIONIC VACUUM ARC PLASMA

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The thermionic vacuum arc plasma is an electrical discharge which ignites in the metal vapors of the anode material continuously generated by bombardment with electrons emitted by the filament and accelerated towards anode. Due to the fact that the cathode and the vacuum vessel are grounded and the anode is high positively, the metal vapors plasma potential is also elevated against ground. It results that the plasma ions will be accelerated towards the vacuum vessel wall, gaining an energy equal with the plasma potential drop. Consequently, during thin films deposition on a substrate, the growing film is a result of metal atoms and also energetic ions bombardment. Because the discharge is generated in high vacuum condition and the deposited film is bombarded with energetic ions, nanostructurated thin films with high purity, increased adhesion, low roughness and compact structure it is obtained. This type of arc discharge enables the control of plasma process parameters like deposition rate, ion kinetic energy and plasma ionization degree by means of a simple choice of the operating parameters.

The purpose of this paper is to investigate the ion energy distribution in thermionic vacuum arc (TVA) plasma. Using emissive probe technique spatial plasma potential distribution has been measured. Experimental results show that the spatial distribution of the plasma potential strongly depends on operation parameters like arc current, arc voltage, relative position of the electrodes and anode material. In some conditions, the anode plasma potential is constant and close to the anode potential. Also, a sharp potential drop characterizes the potential distribution between the anode plasma and the vessel walls. Moreover, we have analyzed the equivalent electric circuit of the plasma during arc discharge operation. The total anode discharge current is the sum of thermoelectric current flowing from filament and the current flowing from anode to the vessel walls. The value of the current intensity, which flows to the vessel, is directly proportional with the arc voltage and it is a measure of the plasma ionization degree. In some experimental conditions, the value of this current intensity reaches up to 25 % of total anode discharge current.

In order to obtain the ion energy distribution, a magnetic deflection ion energy analyzer was used. It was found that ions have quasi-monoenergetic energy and its value is strongly related to the plasma potential distribution. The optical emission spectroscopy measurements confirm these results denoting that ions are quasi-monoenergetic and highly energetic (up to 1 keV). Consequently, the thermionic vacuum arc is a source of plasma with high ionization degree and quasi-monoenergetic high energy ions and these parameters can be fully controlled during deposition process.

DESTRUCTION OF DIRECT BLUE 106 DYE IN UNDERWATER DISCHARGE

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Direct Blue 106 dye comes under group Organic Synthesis Dyes. By definition Dyes can be said to be colored, ionizing and aromatic organic compounds which shows an affinity towards the substrate to which it is being applied. One characteristic of dye is that the dyes must get completely or at least partially soluble in which it is being put to. The rule that we apply to other chemicals is similarly applicable to dyes also. For example certain kind of dyes can be toxic, carcinogenic or mutagenic and can pose as a hazard to health. Direct Dyes are one of the most popular dye groups. They have a wide range of applications because they are often cheap and easy to apply. Their chemical composition consists of salts of complex sulfuric acids. They are usually soluble in water and shows good affinity for vast fiber types and thus they are applied to numerous substrates for example to textiles, leather, plastic, paper etc. in liquid form. Due to their wide range applications, the waste water containing these dyes can be a great environmental problem. It is easier to decompose these dyes directly in the liquid phase. One possible way how to do this is an application of underwater discharge.
This contribution presents results of Direct Blue 106 destruction in this discharge. Underwater discharge is a promising environmental process to water treatment. In this study we have used underwater capillary discharge. An underwater discharge generates the non thermal plasma very similar to gas corona discharge but it presents several physical differences. There is a lower ionic mobility in the bulk liquid; on the other hand, the electron density and electron collision frequency are very high. This discharge configuration is relatively new one and fully combines both gas and liquid phase discharges. The gas bubbles are introduced into the system by thin stainless steel capillary that play simultaneously a role of HV pin electrode. Thus the HV pin electrode is covered by thin gas layers and the discharge is generated in the gas phase in pin to plane configuration. The discharge streamers (plasma channels) generated in the gas phase are long enough (up to 1 cm) and thus they introduce into the liquid phase and further propagate in it. The initial conductivity value of 30 $\mu S.cm^{-1}$ was obtained using salt; the starting dye concentration was 20 $mg.l^{-1}$. The DC 50 voltage of 1.5 kV to 3.0 kV was applied to generate the discharge at mean current of 10 mA to 30 mA was used. The system was bubbled through the high voltage capillary electrode by He, Ar and N_2 at the gas follow of 200 sccm. The dye destruction rate is directly proportional to the applied discharge current, so the highest efficiency was reached at the current of 30 mA. The destruction rate was strongly dependent on the filling gas. While using He and Ar only 4 % destruction was obtained during the 20 minutes treatment the decomposition of 52 % was reached if nitrogen was introduced into the high voltage electrode. This great difference is probably connected not only to the production of hydrogen peroxide that seems be usually the main oxidative specie in under water discharges but also atomic and excited nitrogen particles, both atomic and molecular, can have very positive effect in the dye destruction. The detailed study of the kinetic mechanisms leading to the Direct Blue 106 dye destruction will be a subject of the further studies.

Acknowledgements
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Key words: underwater discharge, capillary discharge, dye, Direct Blue 106

EXPERIMENTAL STUDY ON THE HEAVY PARTICLE DENSITY BY RAYLEIGH SCATTERING IN MICROWAVE INDUCED DISCHARGES

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In this work a surface wave sustained microwave discharge has been investigated. The axial profiles of the heavy particles density and temperature (n_h and T_h) are presented. The method to analyze these crucial gas properties is Rayleigh scattering. This active laser spectroscopy technique is applied to a 2.45 GHz microwave discharge at pressures range of 4-40 mbar in different gases.
An experimental setup originally used for Thomson Scattering is employed to determine the Rayleigh scattered laser light. A triple grating spectrometer and an *i*CCD are used to captured the light and since the *i*CCD is two-dimensional, spatial resolution can be used to remove stray light other than Rayleigh scattered one.
A linear decreasing temperature profile was observed from the launcher (values of T_h = 750 K) to the end of the plasma in pure Argon (around 400 K). That result is a function of the gas pressure.
The axial dependency in pure argon can also be described by a heat balance model. Therefore the electron temperature and density determined by laser scattering on free electrons was used in a heavy particle heat balance equation to calculate and compare the heavy particle temperatures.
At admixtures of molecular gasses the temperature of the heavy particles has a different trend. The result of hydrogen admixtures is a higher gas temperature close to the launcher (values of T_h = 1100 K) followed by a plateau-like shape and step decrease at the end of the discharge.

EFFECTS INDUCED BY NUCLEAR DEFORMATIONS IN GROUND STATE ELECTRON ENERGY AND ELECTRON CORRELATIONS OF MULTIPLY CHARGED HELIUM LIKE IONS IN HIGH-TEMPERATURE PLASMA

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Abstract

Multiply charged isoelectronic Helium like ions in high-temperature astrophysical and laboratory plasma possess specific properties and characteristics caused by the non-compensated by electrons long-range Coulomb field of the nuclei. The Coulomb field plays also the significant role in all interaction processes of multiply charged ions with electrons and photons in plasma

This field determines the possibility one or two electrons to occupy highly excited quasidiscrete (autoionized) states, outside the ionization limit. There are two decomposition channels of the excited ion: autoionization and radiation. In that case one can observe several resonance processes, for example radiative recombination (RR).

In the case of electron capture the decomposition channels of double excited ion are two also: autoionization and radiation. In the case of interaction with electron having the appropriate resonance energy, the radiative decomposition of double excited ion realizes by photon emission and electron transition into bound state. When the radiative transition realizes by the internal electron, the process is dielectronic recombination (DR).

The opposite effects of the influence of the specific electron processes on the nucleus, that is manifested as a deviation of the pure nuclear Coulomb potential and the nuclear excitation by electron capture (NEEC). Nuclear motion, nuclear mass and nuclear size exert an influence over the processes in the electron system also.

The proposed work concerns for the first time and studies the effects resulting from nuclear deformations on the formation of the electron energy quantities of multiply charged ions. In the current stage the investigations are performed on the base of obtained numerical results for the ground state energies, mass corrections and mass correlations of the electronic systems for multiply charged He like ions with charge Z from 2 to 118. The nuclides of all existing isotopes are included. A modified method is used based on explicitly correlated wave functions (ECWF) approach. Staggering effects of the electron energy quantities with nuclear magic numbers by N (number of neutrons) are investigated for each value of Z (number of protons). The effects of nuclear deformations on the electron energy quantities are also investigated through the formation of all nuclear deformation multiplets.

The extremely high accuracy of the obtained numerical results allows their application in precise approaches for plasma diagnostics.

THOMSON AND RAYLEIGH SCATTERING MEASUREMENTS ON A LOW PRESSURE MICROWAVE INDUCED ARGON PLASMA: THE EFFECTS OF HYDROGEN ADDITION

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The electron temperature and density are important plasma parameters that need to be measured to get insight into plasma dynamics. An other important parameter, especially in the case of molecular species loading, is the gas temperature.
Thomson scattering is an accurate and non-intrusive diagnostic tools which gives the electron density and the bulk electron temperature. The gas temperature is obtained by Rayleigh scattering which is proportional to the density of heavy particles (for a fixed pressure).

In this study, we present the investigation of a 2.45 GHz Microwave discharge which was operated between 4 and 40 mbar for a pure argon discharge with different hydrogen admixtures (from 0 up to 3 %).
The Thomson and Rayleigh signals are resulting from the elastic scattering of a monochromatic photons beam (produced by a frequency doubled Nd:YAG laser) respectively by free and bound electrons. The Thomson signal however is much more Doppler broadened than the Rayleigh signal, which makes it possible to filter out the Rayleigh signal by applying a notch filter. This filtering is done optically by the use of a Triple Grating Spectrometer (TGS). A Raman scattering spectrum at a given pressure allows us to get an absolute calibration of the signal.

The electron temperature and density were measured as a function of different plasma parameters. It is shown that the electron density decreases with the admixture of hydrogen while the electron and gas temperatures increase. For each set of parameters, measurements were done as a function of the distance from the launcher. By partial binning of 1-D spatially resolved pictures, the electron density and temperature at the end of the plasma column have been obtained. For some fixed conditions, radial profiles were also done and show a good agreement with the fitting of a Bessel function.

SPUTTERING HOLLOW CATHODE DISCHARGES DESIGNED FOR LASER APPLICATIONS

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Hollow cathode discharges (HCD) have been studied extensively for many years due to their wide range of applicability in different fields: atomic spectroscopy, vacuum microelectronic, material processing, etc. Due to the efficient sputtering and the high density of rare-gas ions in the hollow cathode discharge (HCD), it is widely used as active medium for the excitation of laser oscillation on ion transitions of non-volatile metals (Cu, Au, Ag, etc.) in He, Ne, or other rare-gases. By experimental studies and theoretical modelling of the plasma processes in the hollow cathode discharge, a significant contribution to understanding the physics of processes in the discharge could be achieved, which will improve the results of various HCD applications.

In this work we present Plasimo simulations of a HCD used for laser applications. Among other facilities, Plasimo allows easy configuration of the discharge geometry, pressure and composition of the background gas, electrode potentials, etc. A time dependent sub-model is used to describe the behaviour of the plasma species. It is based on the fluid approach, solving the mass, momentum and energy balance equations together with Poisson's equation.

The model has been applied to a longitudinal HCD in a cylindrical geometry with two anodes at both sides. Copper is chosen as cathode material and the discharge operates in He with a small admixture of Ar that has been added to increase the sputtering efficiency. The experimentally determined optimal conditions for lasing of the IR copper ion line (780.8 nm) are used as input conditions for the simulation model. The observed quantities are compared with the experimental data, obtained for the same discharge tube and operating conditions.

MONTE CARLO SIMULATION OF A SPUTTERING HOLLOW-CATHODE DISCHARGEFOR LASER APPLICATIONS

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We report on a kinetic model that computes the electron behaviour in a hollow cathode discharge (HCD). It is part of the PLASIMO toolkit and based on a Monte-Carlo (MC) technique.

The model is tested by varying the input parameters and by comparing the output with the output obtained by the freeware Boltzmann equation solver BOLSIG+. The results show that the MC model gives reliable information about the behavior of the electrons in the discharge.

One important output delivered by the MC model is the electron energy distribution function (EEDF) from which, among others, the mean electron energy can be calculated. This quantity can be used for the analysis of the discharge and as an input parameter for fluid models.

The MC module is applied to the case of a HCD for laser applications. Analysis of the output data and its adequateness is done. Future developments of the model are discussed. One important goal is to use the MC module as a part of a hybrid model, in which it can be used to describe the electrons and their energy. Another application is to employ the MC module as an independent kinetic model for a HCD to get insight in the *effective* secondary emission coefficient. In this application the module will determine at every time step the loss of electrons leaving the simulated volume and the creation of electrons by ion collisions with the cathode wall.

LOW FREQUENCY OSCILLATIONS IN RF ARGON PLASMA AT ATMOSPHERIC PRESSURE

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The focus of this study is an atmospheric pressure non-thermal capacitively coupled RF discharge. It is created between two parallel electrodes – a powered one supplied by 13.56 MH alternative current, and a grounded one. Feed gas argon flows between the electrodes and is ionized. Plasma torch is studied by means of a time dependant two-dimensional fluid model. Low frequency oscillations of the order 0.1 MH are observed in the discharge. The oscillation frequency decreases with increasing the distance between the electrodes. A saturation of this dependence occurs above certain distance. Our simulation displays the relation of this process with a variation in the electrodes sheath regions width. A particular process in the considered kinetic scheme could be identified as playing a key role for the observed phenomenon. It is the excitation of an Ar atom to its first excited level as a result of a collision with an electron. A particular spatial distribution of the discharge species for small distances between the two electrodes (less than 1 mm) is observed. The relation between kinetics and geometry is discussed.

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THE EFFECT OF ELECTRON–NEUTRAL COLLISION FREQUENCY ON SURFACE–WAVE–SUSTAINED ARGON PLASMA MODEL

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Axially inhomogeneous Argon plasma column sustained by travelling electromagnetic surface wave is theoretically studied by means of a self-consistent model. The model is based on the complete set of equations describing both the electrodynamic of the wave propagation and the kinetics of electrons and heavy particles. The propagation of the electromagnetic azimuthally symmetric TM surface wave along the plasma column is described by the Maxwell's equations. The influence of the collisional damping on the electromagnetic wave propagation and attenuation characteristics is studied by using the exact expression for the plasma permittivity including the electron–neutral collision frequency. The phase and attenuation diagrams and the axial distribution of the electrons are obtained and compared at various effective electron–neutral collision frequencies (ν_{eff}) and with the case of collisionless plasma ($\nu_{\text{eff}} = 0$). A strong dependence on the collision frequency is obtained even at not very high pressure.

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A REVIEW ON LAMB´S ATMOSPHERIC OSCILLATIONS USING INITIAL VALUE PROBLEM APPROACH

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Abstract. Waves at a surface of discontinuity in the atmosphere is analysed in 1910 by Lamb **[1]**, who derived, using normal mode approach, an analytical dispersion relation for a discrete mode (surface mode). Lamb examined the case of waves propagated along a horizontal plane where the equilibrium temperature is discontinuous. For simplicity, the upper region and the lower region are considered incompressible. The oscillations are treated in the ideal (dissipationless) limit and the uniform gravitational acceleration is taken to be co-aligned with the preavailing temperature gradient. In this work, in order to show how the modes appear in the response of a surface discontinuity to an initial perturbation, we consider the initial value problem (IPV). The main difference from the standard analysis is that solutions to the linearized equations of motion which satisfy general conditions are obtained in terms of Fourier-Laplace transform of the hydrodynamics variables . These transforms can be inverted explicitly to express the fluid variables as integrals of Green´s functions multiplied by initial data **[2-4].** In addition to discrete mode (surface mode), a set of continuum modes due to a branch cut in the complex plane, not treated explicitly in the literature, appears.

References:

[1] Lamb, H. Proc. Lond. Math. Soc. A 84 , 1910, pp. 551-572
[2] Ott, E., Russell, D. A.. Physical Review Letters, Vol. 41, Issue 15, 1978, pp.1048-1051
[3] Russell, D. A.; Ott, E. Journal of Geophysical Research, Vol. 84, 1979, pp. 6573-6579.
[4] Bogdan, T. J.; Cally, P. S.. Proc. R. Soc. Lond. A, Math. Phys. Eng. Sci., Vol. 453, No. 1960, pp. 943 - 961

AVOIDED CROSSING OF MODES OF A FINITE TARGET WITH ADIABAT SHAPING IN INERTIAL FUSION IMPLOSIONS

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Abstract. In Inertial Confinement Fusion (ICF), a cold target material is accelerated by a hot low density plasma. In this work, the small amplitude disturbances in ablative Rayleigh-Taylor instability in the presence of entropy gradients **[1-2]** is studied using a sharp boundary approximation **[3]**, being the inverse entropy-gradient scale length the quantity $K_o = \dfrac{\partial LnS_o}{\partial y}$. For simplicity, the target considered here is a finite incompressible slab. Due to ablation, the phenomenon of the interactions of two types of modes (Rayleigh mode and entropic mode) is shown. This manifiest itself in the occurrence of rapid shifts of rate growth (bumping, avoided crossings). The entire situation is strongly reminiscent of the well-know "avoided crossings" of modes of two coupled oscillators. The growth rate of one mode (Rayleigh mode) approaches that of another one (entropic mode) which is "bumped" to a quite different rate growth, while the "bumping" mode settles at roughly at the original rate growth of the bumped mode **[4-5].**

References:

[1]Gardner, John H.; Bodner, Stephen E.; Dahlburg, Jill P. Physics of Fluids B: Plasma Physics, Vol. 3, Issue 4, 1991, pp.1070-1074.
[2]Anderson, K.; Betti, R. Physics of Plasmas, Vol. 10, Issue 11, 2003, pp. 4448-4462 .
[3]Piriz, A. R.; Sanz, J.; Ibañez, L. F. Physics of Plasmas, Vol. 4, Issue 4, 1997, pp.1117-1126
[4]Osaki, Y. Astronomical Society of Japan, Publications, Vol. 27, no. 2, 1975, pp. 237-258
[5] Christensen-Dalsgaard, J. Mon. Not, R. Astr. Soc.Vol. 190, 1999, pp, 765-791

THE INFLUENCE OF A SEMI-INFINITE ATMOSPHERE ON SOLAR OSCILLATIONS

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Abstract. The influence of a semi-infinitive atmosphere on solar investigations is investigated using a model in which the corona is represented by a gravitationally stratified fluid. The solar corona can be modeled as a semi-infinitive region of plasma that occupies the space above the xy- plane in Cartesian coordinates with the z-axis taken along the gravitational acceleration $\vec{g} = -g\vec{u}_z$. This assumption is reasonable, as the plasma density of the atmosphere is much lower than the density of the photosphere. So, we consider the phostosphere as a solid and immobile boundary for the atmosphere. The standard mathematical procedures in Helioseismology field are based on normal mode approach for various solar models **[1-4]**. The region is assumed quasi-isothermal and without magnetic fields. In this work, in order to show how the modes appear in the response to an initial perturbation, we consider the initial value problem (IPV) **[5-6].** The p-modes and g-modes possess only continuous spectra –as opposed to discrete spectrum like that previous investigators found for this problem- and the solution to the initial value problem is obtained through an appropiate Green´s function.

References:

[1]Vanlommel, E, Cadez, V. M. Solar Physics. Vol. 182, 1998, pp. 263-281
[2]Schmitz, F, Steffens, S. Astron. Astrophys. Vol. 334, 1999, pp. 973-980
[3] Cadez, V. M., Jovanovic, G. Publ. Astron. Obs. Belgrade. Vol. 84, 2008, pp. 495-498
[4]Goedbloed, H, Poeds, S. Principles of Magnetohydrodynamics , 2004, Cambridge University Press, Cambridge, UK.
[5]Ott, E., Russell, D. A.. Physical Review Letters, Vol. 41, Issue 15, 1978, pp.1048-1051
[6] Russell, D. A.; Ott, E. Journal of Geophysical Research, Vol. 84, 1979, pp. 6573-6579.

INITIAL VALUE PROBLEM APPROACH OF TWO REGIONS MODEL OF SYSTEM SOLAR: THE CONTINUOUS SPECTRUM

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Abstract. The standard mathematical procedures in Helioseismology field are based on normal mode approach for various models of solar interior and atmosphere [**1-2].** We consider a two region model of a system solar interior and solar atmosphere. For simplicity, the two different regions are assumed quasi-isothermal, semi-infinite, without magnetic fields and separated by a boundary $z=0$. It was found useful to phrase of stability as initial value problem (IPV) in order to ensure the inclusion of certain continuum modes otherwise neglected **[3-4].** In addition to discrete mode (s mode), a set of continuum modes due to a branch cut in the complex plane, not treated explicitly in the literature, appears. It will be seen that an ambiguity of the usual normal mode method is avoided.

References:

[1]Vanlommel, E, Cadez, V. M. Solar Physics. Vol. 182, 1998, pp. 263-281
[2]Schmitz, F, Steffens, S. Astron. Astrophys. Vol. 334, 1999, pp. 973-980
[3]Ott, E., Russell, D. A.. Physical Review Letters, Vol. 41, Issue 15, 1978, pp.1048-1051
[4]Russell, D. A.; Ott, E. Journal of Geophysical Research, Vol. 84, 1979, pp. 6573-6579.

DIFFERENTIAL CROSS SECTION IN PIC-MCC SIMULATION OF PLASMA-SOLID INTERACTION

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To understand plasma-solid interactions is essential in modern plasma-assisted technologies and also for the interpretation of plasma probe diagnostics. In low-temperature plasma, which is characterized by low degree of ionization, collisions between charged particles and neutrals play an important role during the sheath formation near the immersed solids. This is true especially in the case of middle and higher pressures. The theoretical analysis of processes taking place in high-pressure plasmas is very complicated due to these collisions. The known Langmuir theory does not fit for weakly ionized plasma under high neutral gas pressures; therefore, computer simulations are useful.
The particle simulations of plasma provide results for both macroscopic and microscopic levels. Their time requirements are, however, very high and many techniques are being developed to speed up the calculations. Widely used are the simulations based on Particle-In-Cell technique with Monte Carlo collisions (PIC-MCC). So far, the PIC-MCC simulations have included collisions with either constant or energy-dependent cross sections. Recently, the Monte Carlo collision model has been improved in accuracy and speed [1]. However, this model still uses energy-dependent total cross sections. The most accurate and realistic simulation of collisions is needed in higher-pressure plasmas since the propagation of the charged particles through sheath, which is influenced by collisions, determine the probe current.
Three different Monte Carlo simulations of collisions are presented – models of collisions with constant and energy-dependent total cross sections and model with energy-dependent together with angle-dependent differential cross section. We implemented these simulations to a two-dimensional model of plasma-solid interaction including electropositive plasma in the positive column of DC glow discharge. The specific forms of the angle-dependence of cross sections were found among previous experimental, computational or analytical results. We studied the formation of the sheath and pre-sheath near the Langmuir cylindrical probe in static mode with the electron-attracting potential applied. Physical results such as probe current, spatial distribution of electrostatic potential, electron and ion distribution functions and angular distributions were compared among all three types of simulations. Computational results, including time requirements for each configuration under a certain value of pressure, together with physical results show which one of the three described methods is suitable to use in the future PIC-MCC simulations.

References:

[1] R. Hrach, Š. Roučka, V. Hrachová, L. Schmiedt, Vacuum 84 (2010) 94-96.

COMPARISON OF SEVERAL ALGORITHMS OF THE ELECTRIC FORCE CALCULATION IN PARTICLE PLASMA MODELS

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Computer modelling is a very important approach in plasma physics. This work is focussed on the molecular dynamics, i.e. deterministic particle modelling, which is usually used for the study of interaction of plasma (both low- and high-temperature) with immersed solids. It is used not only for the understanding and predicting of plasma behaviour near substrates or walls but also for the interpretation of experimental data measured by probes.

The calculation of the electric force is one of the critical points in molecular dynamics, especially in the view of speed. Apparently the most widely used algorithm for this calculation is the particle-in- -cell algorithm. Its popularity is caused by these convenient properties of it: First, it allows to apply the boundary conditions (namely electrodes) easily, second, it is relatively fast (from the point of view of molecular dynamics) and third, its implementation is simple enough. However, this method is approximative as it underestimates the short-range interactions between charged particles. It has been shown that this inaccuracy influences especially the study of processes in magnetized plasmas.

In this work, an improvement to the particle-in-cell algorithm is suggested. It is then included into a set of algorithms which are tested against each other in a self-consistent two-dimensional magnetized plasma model. Besides the “improved” particle-in-cell, this set includes the “pure” particle-in-cell with nearest-grid-point charge counting, the cloud-in-cell algorithm and the direct application of Coulomb's law. In Coulomb's law calculations, also a method of reducing the nonphysical heating is tested. The testing is carried out for various plasma and computation parameters. The accuracy of the algorithms is compared in several ways – direct force comparison, particle trajectories, energy conservation and Maxwell-Boltzmann distribution conservation. The speed of the algorithms is compared, too.

RANDOM TRANSITION BETWEEN TWO TEMPERATURE PROFILES IN MAGNETIZED PLASMA

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Experimental results in pellet fuelling of Ohmic and Lower Hybrid driven discharges show for electrons in the central region a transition between two temperatures, almost regular in the first case, and almost random in the second one, [1], on the scale of few seconds.

The Langevin equations are used to describe the transport of the guiding centers of charged particles perpendicularly to the main magnetic field [2]. The stochastic transition between the two temperature states is described by a randomly interrupted noise [3]. The variation of the running diffusion coefficients in spatial radial direction is analyzed for some different temperature profiles.

References

[1] A. Geraud, J. Bucalossi, et.all, Journal of Nuclear Materials 337-339 (2005) 485
[2] R. Balescu, Aspects of anomalous Transport in Plasmas, 2005, IOP (Taylor and Francis, Series in Plasma Physics) London
[3] C. W. Gardiner, Handbook of Stochastic Methods: for Physics, Chemistry and the Natural Sciences, 2004, Springer Series in Synergetics

EXPERIMENTAL RESEARCH OF SLIDING SURFACE DISTRIBUTED NANOSECOND DISCHARGE IN SUPERSONIC AIR FLOW

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Using of high-current discharges gives a possibility to apply non-equilibrium plasma in terms of operation with gas flow in plasma dynamics problems [1]. As for initiation of nanosecond surface sliding distributed discharge (plasma sheet), it enables us to put energy in a low-thickness (~1mm) close-to-the-surface gas layer. The aim of this work was to carry out an experimental investigation of plasma sheet radiation spatial structure and spectrum characteristics in high-velocity air flow.

The experiments were held on a shock tube with a discharge section, where air flows of Mach from 1.1 till 1.5 (relevant velocities up to 1600 m/s), densities of 0.08-0.40 kg/m^3, Reynolds numbers in average of 10^5 were achieved [2]. Two plasma sheets were initiated on two opposite sides of the discharge section. The applied pulse voltage was 25kV. The discharge itself lasted for 200 ns. It evolved transversally to the flow direction; the width of plasma layer was ~0.5 mm.

The AVASpec-2048FT spectrometer (174-1100 nm spectral range) was used to register radiation spectra. Plasma sheet glow was registered integrally and with nanosecond resolution by digital cameras.

It was shown that the emission spectra of pulse surface sliding discharge were determined in the air by electronic-vibrational bands of N_2 second positive system and N_2^+ first negative system. One can see typical atoms lines of hydrogen, oxygen and nitrogen in the spectra. The long-wave-line part of spectrum is more intensive in supersonic flow after the shock wave.

It was found that close to the surface in the boundary layer of supersonic flow the character of the flow influenced the geometry of discharge channels development. Considerable changes of plasma discharge glow structure were observed in different areas of boundary layer, specifically in laminar area glow was smooth and homogeneous, while for the area of turbulence it was patchy, and spotty, more like forming different plasma structures of various calibers [2]. It was shown that due to the strong dependence of radiation intensity on local value of reduced electric field *E/N* and due to the short time of the discharge compared with gas dynamics times the distribution of the plasma discharge radiation intensity does correspond with the instant distribution of gas' density. This makes it possible to get spatial calibers typical for laminar and turbulent flow areas of boundary layer by relevant mathematical analysis of the spatial distribution of discharge glow.

References

1. *Bletzinger P., Ganguly B.N., Van Wie D.M. and Garscadden A.* // Journal of Physics D: Applied Physics. 2005. Vol. 38. No. 4. P. R33-R57.
2. *Latfullin D.F., Mursenkova I.V. and Znamenskaya I.A.* Supersonic Boundary Layer Investigation using Surface Nanosecond Discharge. Proceedings of 13th International Symposium on Flow Visualization (ISFV-13) and 12th French Congress on Visualization in Fluid Mechanics (FLUVISU-12). Nice, France, July 1-4, 2008. CD Rom Proceedings, 146-080414.pdf.

A NOTE ON THE TRAPPED ELECTRON DUST GRAIN CURRENT

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Abstract
It is shown that when the non-isothermal trapped electron current is rederived based on the orbit-limited motion theory, the variable dust charge can be expressed in terms of the Lambert function. One can then take advantage of this new transcendental function to illustrate how variable-charge nonlinear trapped dust modes can be investigated semi-analytically.

Keywords: Variable dust charge, orbit-limited motion theory, trapped electron current, Lambert function.

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LASER DRIVEN ION ACCELERATION IN MASS LIMITED TARGETS

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Ion acceleration in targets irradiated by short ultra-intense laser pulses has been studied here with analytical model and 2D3V PIC simulations, which describe the complete process from the electron acceleration in the laser field to the ion bunch formation. Simulations were performed for µm-scale sizes cycle and plane targets (foils and foil sections) including curve foil sections. Energy spectra of fast ions, laser conversion efficiency to fast ions and the divergence of ion beams are compared for various types of targets. Laser pre-pulse influence on ion acceleration has been considered. It is found that maximal energy of ions and its directionality can be significantly enhanced by choosing of tailored targets.

SIMULATION OF DEFECTS IN FUSION PLASMA FIRST WALL MATERIALS

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ABSTRACT

The first part of the study is devoted to numerical calculations of cascade effects of 14MeV neutron irradiation and the defect creation processes in fusion materials. The second part is study the behaviour of defects in first wall materials containing hydrogen and helium by positron simulation.

Numerical calculations of damages in tungsten, irradiated by fusion neutrons were performed using molecular dynamics (MD) simulations combined with embedded atom method (EAM) potential. The displacement cascades efficiency has been calculated using the Norgett-Robinson-Torrens (NRT) formula, the pair potential of Ziegler-Biersack-Littmark (ZBL) and the more realistic EAM interatomic potential. The pair potential overestimates the defects production by a factor of 2. At higher primary knock-on atom (PKA) energies (E > 100 keV) the ZBL pair potential results and the EAM are comparable. At lower energies the changes in the cascades dimensions at the early stages after the irradiation indicate that the tungsten interstitials are about 2 times more mobile than the vacancies. We found that the most common types of defects are single vacancies, di-vacancies, interstitials and small number of interstitial clusters containing more than 3 atoms.

The properties of defects in fusion materials in presence of hydrogen or helium atoms have been investigated by model positron lifetime quantum-mechanical calculations. The electron and positron wave functions have been obtained in the local density approximation LDA to the two component density functional theory TCDFT. On the bases of calculated results, the behavior of vacancies, empty nano-voids and nano-voids with hydrogen and helium were discussed. It was established that positron lifetime depends on the density of gas atoms inside the nano-void. The calculated values of the positron lifetime correlate with the magnitude of the electron density. The vacancy-clusters without hydrogen or helium are active positron traps. The lattice relaxation of atoms around vacancy reduces the effective vacancy volume and decrease the positron lifetime at a vacancy. Hydrogen and helium presence in the larger nano-voids considerably decrease the positron lifetime.

COMPUTER-SIMULATIONS OF POSITRON INTERACTION IN α-IRON CONTAINING EDGE AND SCREW DISLOCATIONS

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Abstract: Positron annihilation studies have proved to be powerful tool in investigating the defects in condensed matter. The defects in metals sensitively trap positrons and as a consequence, the positron interaction is different from that one in perfect lattice. Dislocations in Iron and other metals are of crucial importance for understanding behavior of fusion materials. In this study dislocations in pure α-Iron have been investigated by model positron lifetime quantum mechanical simulations within Local Density Approximation (LDA). The positron and electron wave functions have been obtained and positron life time is calculated for a bulk Iron lattice, lattice containing (100) edge dislocation, (a/2) <111> screw dislocation and dislocations interacting with vacancies. The obtained calculated values for α-Iron of 146 ps. for edge dislocation and 129 ps. for screw dislocation correlate with available experimental data. Positron lifetime differ when vacancies, or vacancies containing hydrogen or helium atoms interact with dislocation line.

INVESTIGATION OF MATERIALS FOR FUSION POWER REACTORS

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The possibility of application of nuclear-physical methods to observe radiation damage to structural materials of nuclear facilities is nowadays a very actual topic. The radiation damage to materials of advanced nuclear facilities, caused by extreme radiation stress, is a process, which significantly limits their operational life as well as their safety.

In the centre of our interest is the study of the radiation degradation and activation of the metals and alloys for the new nuclear facilities (Generation IV fission reactors, fusion reactors ITER and DEMO). The observation of the microstructure changes in the reactor steels is based on experimental investigation using the method of positron annihilation spectroscopy (PAS).

The experimental part of the work contains measurements focused on model reactor alloys and ODS steels. There were 12 model reactor steels and 3 ODS steels. We were investigating the influence of chemical composition on the production of defects in crystal lattice. With application of the LT 9 program, the spectra of specimen have been evaluated and the most convenient samples have been determined.

NON-DESTRUCTIVE RESEARCH METHODS APPLIED ON MATERIALS FOR THE NEW GENERATION OF NUCLEAR REACTORS

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Abstract. The paper is aimed on non-destructive experimental techniques applied on materials for the new generation of nuclear reactors. With the development of these reactors, also materials have to be developed in order to guarantee high standard properties needed for construction. These properties are high temperature resistance, radiation resistance and resistance to other negative effects. Nevertheless the changes in their mechanical properties should be only minimal. Materials, that fulfil these requirements, are analysed in this work. The ferritic/marternsitic steels and ODS steels are studied in details. Microstructural defects, which can occur in structural materials and can be also accumulated during irradiation due to neutron flux or alpha, beta and gamma radiation, were analysed using different spectroscopic methods as positron annihilation spectroscopy and Barkhausen noise, which were applied for measurements of three different ferritic/marternsitic steels (T91, P91 and E97) as well as one ODS steel (ODS Eurofer).

INFLUENCE OF THE OBLIQUE MAGNETIC FIELD ON THE SECONDARY ELECTRON EMISSION FROM THE PLASMA FACING MATERIALS IN FUSION REACTOR

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The studying of plasma – surface interaction processes is a very important task for realization of the international project ITER. To determine the implantation, deposition, and fuel retention it is necessary to determine correctly the inflow and outflow of charged particles near the surface [1]. The potential drop depends on the reflection and secondary electron – electron emission, since these processes change the electron fluxes to and from the wall. The reflection and secondary electron – electron emission are dependent on parameters of electrons incidence onto the surface, in particular, the energy and angular distributions of impinging electrons [2]. The effect of the magnetic field inclination on the angular distribution of electrons impinging the first wall has not been well described.

In this work we study the influence of the oblique magnetic field on the energy and angular distribution of the electrons bombarding the fusion reactor first wall. Taking into account the revealed dependences of average electron energy and incident angle on the magnetic field angle we calculated the coefficient and the yield of secondary electron emission. It was shown, that the average energy of the electrons bombarding the first wall increases with the magnetic field angle, that means the increasing of the secondary emission coefficient. At the same time, the electron flux to the surface is diminished by oblique magnetic field, that leads to the secondary electron yield decreasing, despite the increasing of the secondary emission coefficient.

References

1. *P. C. Stangeby*, The plasma boundary of magnetic fusion devices, Plasma physics series, IOP Publishing Ltd, 2000.
2. *E.W. Thomas.* Particle induced electron emission // Atomic and plasma-material interaction data for fusion. Vol.1. Vienna. 1991. p. 79.

LASER GUIDING THROUGH AN AXIALLY NON-UNIFORM COLLISIONAL PLASMA CHANNEL

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This paper presents an investigation of laser guiding through an axially non-uniform collisional plasma channel formed by ionizing laser prepulse. Due to self-defocusing of the ionizing prepulse, an axial non-uniform plasma channel is formed. When delayed second laser beam propagating through such preformed plasma channel, on account of non-uniform intensity distribution of laser beam, non-uniform heating of electrons takes place. Non-unform heating diffuses the electrons away from the axis which further enhances the plasma channel. Unbalanced diffraction and refraction phenomenon through such an axial non-uniform collisional plasma channel results into periodic beam width variation with the distance of propagation. Second order ordinary differential equations for the beam width parameter of prepulse and the guided beam have been set up using the moment theory approach. Laser guiding upto several Rayleigh lengths has been observed.

MODELLING AND SIMULATION OF GYROTRONS FOR ITER

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Powerful gyrotrons of the megawatt class will be used for electron cyclotron resonance heating (ECRH) and current drive (ECCD) of magnetically confined plasma in the thermonuclear reactor ITER. For computer-aided design (CAD), analysis and optimization of their performance numerical experiments based on adequate physical models are used. In this paper we outline and illustrate the current status of both the available software tools for numerical simulation of such gyrotrons as well as the novel computer codes of the problem oriented software package GYREOSS which is under development now.