S6 Metal Plasmas by Pulsed Cathodic Arcs and High Power Impulse Magnetron Sputtering

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Cathodic arcs are known as prolific generators of metal plasma, with applications in coatings and as feedstock for broad beam metal ion sources. For some applications, pulsed arcs offer greater flexibility than continuous arcs. Of special interest are the presence and control of multiple ion charge states and the supersonic ion velocity, which have been extensively measured.

In a parallel development, magnetron sputtering has been modified by applying the discharge power in pulses that exceed the conventional rating of "allowable" power density by two orders of magnitude or more. This High Power Impulse Magnetron Sputtering (HIPIMS) is characterized by ionization of the sputtered atoms, in contrast to conventional sputtering where sputtered atoms remain neutral. Measurements indicate the presence of significant amounts of multiple charge states if the discharge is allowed to develop into the runaway phase. The physics of plasma generation is compared, with emphasis of the ionization processes at fractal arc cathode spots versus volume ionization of the magnetron discharge.

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S2 Plasma-Focus Neutron Source

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Plasma-Focus (PF) devices belong to the family of the dynamic, non-cylindrical Z-pinches and they are based on pulsed high-current discharges between two coaxial electrodes, which are usually placed inside an experimental chamber filled up with a working gas. The development of a PF-type discharge can be divided into several phases. The first phase constitutes the initial breakdown of the working gas along a surface of a tubular insulator separating the coaxial electrodes, and the formation of a dense ionized plasma layer (current sheath). During the second phase, the current sheath is driven off the insulator surface and it is accelerated towards the open ends of the electrodes. During the consecutive phases (i.e. the radial compression, the column creation and its disruption) the current sheath collapses rapidly toward the axis of the electrodes where a dense pinch column is formed. The micro-instabilities and turbulences of dense magnetized plasma compressed inside the pinch column lead to the generation of powerful electron and ion beams, intense emissions of electromagnetic radiation and of fusion neutrons (if deuterium is applied as the working gas). In general, the PF device can be considered as a power transformer, in which energy stored in the magnetic field is abruptly converted into energy of the pinched plasma. The

propagation period from the breakdown to the pinch formation takes usually a few microseconds. The final stages of PF discharges are much shorter and they last from several tens to several hundreds of nanoseconds (depending on a PF-device scale).

During the last years the interest in PF devices has been increased, because they are one of the most efficient sources of pulsed fusion neutron emission. Moreover, in comparison to other pulsed neutron sources, which are used worldwide, scaling laws for the neutron yields (as formulated at the beginning of the PF studies) seemed to be very promising. Later investigations, however, which were performed with larger devices, have suggested that there is a certain energy limit above which the scaling law is not valid. Hence, the essential problem to be solved in PF research has always been to discover the physics which dominates the plasma formation. This question is closely related with neutron production mechanisms, plasma dynamics and physics of different phases of such plasma discharges. The experimental studies of high-current PF discharges have been continued at IPPLM in Warsaw, Poland, with the large PF-1000 facility, which can be operated up to 1 MJ. Results of neutron measurements, which were performed at the PF-1000 device during series of experiments in the last years, as well as prospects of a Plasma Focus as a intense-pulse neutron source - are presented and discussed.

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S1 Emissive Probes as Diagnostic Tools for Edge Plasma Turbulence Measurements

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An electron-emissive probe has the capability to deliver a direct approximate measure of the plasma potential Φ_{pl} through its floating potential. This method strongly facilitates measurements of Φ_{pl} and, by use of arrays of emissive and cold probes, allows fast determination of complex edge plasma parameters such as poloidal and radial electric field, radial turbulent flux, Reynolds stress and correlations of these parameters. We developed and regularly used emissive probes in toroidal and linear magnetized plasmas. Usually these were emissive probes consisting of a small loop of tungsten or thoriated tungsten wire heated by an external electric current. Such probe arrangements were used in CASTOR (Czech Academy of Science TORus) in Prague and ISTTOK (Instituto Superior Técnico TOKamak) in Lisbon. By turning on and off the probe heating on a shot-to-shot basis and recording once the cold floating potentials and once the emissive floating potentials, we could compare the

parameters to investigate whether or not emissive probes, through the difference between two hot probe floating potentials, deliver more accurate measures of electric field fluctuations.

A recently constructed probe array in ISTTOK consisting of four emissive probes in a row above each other, thus on the same poloidal cross section, and one cold cylindrical probe was used for the simultaneous determination of the poloidal electric field from the difference between the floating potentials of two unheated probes, respectively of two heated emissive probes. The statistical properties of poloidal electric field and turbulent particle flux were compared. Both, the root mean square of the poloidal electric field and the fluctuation-induced particle flux were found to be significantly larger when measured with the emissive probes. The probability distribution of the particle flux was also found to be more peaked and positively skewed when measured with emissive probes, elucidating the importance of temperature fluctuations for the measurement of the particle flux.

An alternative method to heat a probe to electron emission was used for measurements in the linear helicon plasma of VINETA at the IPP in Greifswald, Germany. A probe consisting of a small 1,5 mm diameter and 3 mm length pin of lanthanum hexaboride was heated by a focused laser beam from an IR diode laser with a power up to 50 W. Such a probe is able to deliver an emissive current of several amperes into the VINETA helicon plasma with a typical density of 3×10^{19} m^{-3} and an electron temperature between 3 and 4 eV.

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S6 Diagnostics of Pulse Low Temperature Plasma Systems during their Application for the Deposition of Oxide Thin Films

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Several types of plasma diagnostic methods were implemented during the deposition of oxide thin films. TiO_x and doped TiO_x films by nitrogen were deposited by low pressure double hollow cathode plasma jet system with DC pulsed plasma excitation and by DC pulsed magnetron sputtering system by use of $Ar+O_2$ working gases. Double hollow cathode plasma jet system contained two *Ti* hollow cathodes with two high density pulsed plasma jets. TiO_x films with anatase structure were deposited by both systems and their deposition rate, roughness, chemical composition, photochemical properties and optical properties were measured. Pulsed plasma in double plasma jet system and pulsed magnetron system was analyzed by time resolved Langmuir probes in order to determine the time evolution of plasma potential, electron concentration and electron distribution function during the duty cycle of discharge pulsing. Optical emission spectroscopy and laser absorption spectroscopy were used for the measurement of plasma compositions. It includes detection of sputtered atoms, determination of absolute value of concentration of metastable argon atoms and their kinetic temperature from Doppler broadening of absorption profile. Influence of pulsed modulated DC bias, which was induced by RF voltage on the substrate with frequency 13.56 MHz and 1 MHz respectively, was investigated and ion flux on the substrate was

monitored as well. Magnitudes of measured substrate ion fluxes were compared with values of substrate heating fluxes measured by thermocouple probe implemented in the substrate. Both pulsed DC hollow cathode system and DC pulsed magnetron system were compared from the point of view of deposited TiO_x thin films and measured plasma parameters including ion and heating fluxes on substrate.

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S6 Surface Modification of Biomedical Materials in Plasma Processes

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Non equilibrium plasmas have permeated so many areas of Science and Technology after Microelectronics and Semiconductors, from Polymers to Biomaterials, from Car Industry to Packaging, from Textiles to Optics, from Paper to Sterilization, from TV Displays to Membranes. Today Plasma Sciences and Technology impacts three different large areas of Life Science, namely: surface modification of biomedical materials (the issue of this talk); sterilization / decontamination; treatments of living tissues. The Special Issue of *Plasma Processes & Polymers* (Vol 3(6/7), 2006) .devoted to "Plasma Processes for Biomedical Applications" from this author is a complete recent review of the many applications of Plasma Science in the field.

Surface modification plasma processes (dry etching, deposition of thin film, grafting of chemical groups), in particular, are often part of procedures optimized to create micro/nano-features on biomedical materials and devices intended to drive selected responses by proteins, cells, tissues and other biological systems in contact with them, to be exploited *in vitro* and *in vivo* in Biomaterials Science, Tissue Engineering, and Biomedical Devices Technology.

This talk, in particular, is be devoted to review surface modification approaches using cold plasmas, some of them developed at the lab of the author, that are able to design regular and random micro- and nano-metric structures of pre determined chemical composition at the surface of biomedical materials. Cell have been seeded in culture onto such surfaces in order to reveal their responses to surface materials features such as chemical composition, roughness, relieves and the like.

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S6 Polymer Surface Treatment Studies for Carboxylic Functionalization Using Solution Plasma Technique

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Non-equilibrium solution plasma treatment of polymer surfaces involves sure possibility of effectively or more selectively functionalizing the substrate. Polymer surfaces to be modified remain in contact with the plasma moderated solution instead of chemically reactive plasma. The UV-radiation produced in plasma formation helps in moderating the reaction solution further by producing additional excited, ionized/dissociated molecules. Interesting feature of the technique also remains in its flexibility to use a wide variety of additives as or in-solution system. This allows and leads to a selective or monotype functionalization of materials surfaces. Such system was studied for the selective carboxylic functionalization of polypropylene surface with the background of our earlier work of hydroxyl functionalization using capillary discharge technique.

Attempt was made by using carbonated water, formic acid, acetic acid. A study over the results using oxalic and fumaric acid as an additive will also be presented. Efforts are for creating possibly maximum proportion of ester bond within the ratio of C-O to O-CO- bond percentages with a long term objective to study the selective functionalization of PP surface using gas phase fluorine derivatisation. We believe that providing full oxidative solution atmosphere around the plasma generation sight will assist in maximizing the ester carbon percentage on the polymer surface.

The XPS analysis was used to detect the bond percentages of different functional groups. Addition of these milder organic acids to aqueous system shows increase in the ester bond percentage with increasing concentration. A ratio of 1:1.5:1 was observed for –C-O: >C=O: O-CO- bond percentiles by the addition of 10-15% formic acid to carbonated water system. Though it was observed that carbonyl percentage also dominates, which may be brought down with increasing the distance between substrate and plasma jet, below the liquid.

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S6 Secondary Electron Emission from Highly Charged Carbon Grains

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Surfaces in contact with a plasma can influence its characteristics and, on the other hand, the impact of plasma particles can change surface properties of materials immersed in a plasma. Carbon is often present in plasma systems either as a building material or a product of technological processes, thus its behavior is an important factor of these systems.

For this reason, we study the changes of electrical properties of carbon surface under impact of energetic electrons and ions. Our investigation method is based on levitation of a single charged grain in the quadrupole. We have used 2-6 micrometer spherical samples from amorphous carbon. These grains with different diameters were charged/discharged by an

electron beam with the energy tunable in a range from 40 V to 10 keV. During this process, the grain charge is continuously monitored. If the grain is charged by an appropriate energy (1-4 keV in our experimental conditions), its charge (and corresponding surface potential and the surface electric field) is set to a value when the yield of secondary emission is equal to unity. The energy of primary electrons falling onto the grain surface is then equal to the difference between the electron beam energy and the grain surface potential. Our investigations reveal that this energy changes proportionally to the grain potential. Since the slope of this dependence does not depend on the grain diameter, mentioned effect can be attributed to an increase of the yield of secondary emission due to a large electric field at the grain surface. Moreover, we have observed a shift of charging characteristics after a long-time electron bombardment. It suggests that the surface structure is modified by the impinging electrons. Such effect has important consequences in many applications using electron beams or hot plasma.

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S6 Antibacterial Effect of Metal Modified TiO_2/PECVD Films

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This paper deals with antibacterial activity of metal treated TiO_2 films. The TiO_2 films were deposited on glass substrates by plasma enhanced chemical vapor deposition (PECVD) in a vacuum reactor with radio frequency (RF) low temperature plasma discharge in the mixture of oxygen and vapours of titanium isopropoxide (TTIP). The depositions were performed at different deposition conditions. Subsequently silver nanoparticles were deposited on the surface of TiO_2 films by different methods. Photocatalytic decomposition speeds of the model organic matter (Acid orange 7) were evaluated for metal modified and unmodified TiO2 films. Selected samples were furthermore used for tests of antibacterial activity. These tests were performed on Gram-positive bacteria *Staphylococcus aureus*. The results clearly proofed that presence of metal clusters resulted in enhancement of the photocatalytic activity which was up to four times higher than for untreated TiO_2 films.

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S6 Sterilization by DC Discharges at Atmospheric Pressure

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Three types of DC discharges in atmospheric pressure air in point-to-plane or point-to-water level gaps are presented. A *streamer corona* with small current pulses (~10 mA) of streamers with a 10-30 kHz repetitive frequency generates very cold non-equilibrium plasma (300-350 K). With increasing applied voltage, the streamer transits to a *transient spark*: a spark with very short (~100 ns) current pulses (~1 A) of 0.5-5 kHz repetitive frequency and very limited energy. Thanks to the very short spark pulse duration given by the small internal capacity of the discharge system and the limiting series resistor, the plasma cannot reach LTE conditions (500-1000 K). With an appropriate ballast resistor, this transient regime evolves into a pulse-less discharge, with the cathode fall and positive column and other properties of a typical *glow discharge*. It has descending current-voltage characteristics and provides relatively hot (1500-2000 K), yet non-thermal plasma.

The emission spectra and the measured temperatures indicate that these discharges generate non-equilibrium plasmas with various excited species, molecular and atomic radicals. Such plasmas induce chemical and biological effects important for applications, such as VOC abatement or sterilization.

Sterilization of selected bacteria (*S. typhimurium, B. cereus*) or spores (*B. cereus*) by these DC discharges in both polarities was tested. Bacteria in water or physiological solution were treated both in a static and a flowing regime. Satisfactory results were obtained in the static regime, with the highest efficiency in the transient spark with ultra short high current pulses. Glow discharge was efficient but too energetic. In the flowing regime treatment by 5 parallel transient sparks, higher decontamination efficiencies were achieved in shorter treatment times. Streamer corona that was weak in the static regime was found efficient in the flowing regime with the treated medium flowing directly through the high voltage needle electrode and thus through the active corona zone. The spores were treated by streamer corona on various surfaces (paper, plastic or aluminum foil).

Electrical discharge and emission spectroscopic investigations indicated important bio-inactivation mechanisms, mainly the major role of radicals and active species, generated especially in TS with high short pulses. In addition, we are investigating an application of TBARS (thiobarbituric acid reactive substances) method (spectrometric detection of the products of lipid peroxidation) to examine the effect of radicals on bacteria. Comparing the effects of a direct vs. remote plasma exposure is envisaged in near future. The bacteria were handled and their population evaluated by standard microbiology cultivation procedures. In parallel, we are developing a rapid fluorescence spectroscopic method for bacterial live/dead population evaluation using SYTO 9 and Propidium iodide fluorescent stains.

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S6 Structural and Bonding Characteristics of a-C:H Films Prepared by Plasma Enhanced Chemical Vapor Deposition at Different Temperature

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Amorphous hydrogenated carbon (a-C:H) films are frequently deposited by plasma-enhanced chemical vapour deposition (PECVD). This technology is very promising because it enables to control the film quality; integrates easily into the state-of-art microelectronic technologies; and has a low cost, high efficiency, and reproducibility. Recently, it has shown that such layers have various optical and electrical properties. Then, as such layers can be easily etched by oxygen-fluorine plasma, they can be used for a great number of optoelectronic components (light source, detector, amplifier, waveguide, optical sensor, etc.).

The methane was introduced into capacitively coupled plasma reactor through the shower head, which is also an upper electrode with 12 cm diameter. Gas was flown vertically toward the substrate on bottom electrode. A n-type silicon wafer with resistivity 2-7 Ωcm and (111) orientation was used as the substrate for the a-C:H films. Prior to deposition, standard cleaning was used to remove impurities from the silicon surface, and the 5% hydrofluoric acid was used to remove the native oxide on the wafer surface. The wafer was then rinsed in deionised water and dried in nitrogen ambient. The flow rate of CH_4 gas was 40 sccm. The deposition temperatures were for samples T7 - 300, T8 - 400 and T9 – 500 °C respectively. The concentration of species in the a-C:H films was determined by Rutherford backscattering spectrometry (RBS). Chemical compositions were analyzed by infrared spectroscopy. The IR spectra were measured from 4000 to 400 cm^{-1}. The hydrogen concentration was determined by the elastic recoil detection (ERD) method.

The experimental results obtained from this work can be summarized as follows. The RBS results showed that the concentration of C in the films dependent a little on the deposition temperature. The concentration of hydrogen dependent on deposition temperature and increases from 17 to 24 at.% with decreasing of deposition temperature. The results presented demonstrate that 2.4 MeV He ERD analysis may be successfully used to measure the hydrogen concentration. IR results showed the presence of C-H specific bond. The most important result is that the sp^3 hybridisation is stronger in the sample deposited at higher temperatures. This is evident for the wave numbers between 2800 and 3150 cm^{-1} where a stringer sp^3 CH_3 feature appears at 2870 cm^{-1} compared to the low temperature sample T8. At lower wave numbers for the low temperature sample the sp^2 CH olefinic related peak is more pronounced compared to the high temperature case. For samples beside the sp^3 bonds sp^2 and graphite like related peaks can be assigned.

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S6 Aplication and Analysis of Silver on Textile Polymers

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Textile materials are important from technical point of view. They have high porosity, high interior surface, along with high strength and structure flexibility.

Textile materials are ideal carriers of nanoparticles whereas catalytic or barrier effect of these nanoparticles can be synergic advanced. The immobilization and fixation of this on textile surface are the main problems in application.

The influence of plasma treatment on sorption of silver nanoparticles from liquid on textile was tested in this study.

The silver in nanoparticle form can be used like barrier surfactant and it have antibacterial effect. Nanoparticles size approximately 20 nm (electrochemically prepared) were used in this study. As a carriers of silver nanoparticles were used polymeric materials in fabric and foil forms. The polyamide, polypropylene and polyester were used. Textile samples was treated by DCSBD (diffuse coplanar surface barrier discharge) plasma source in different times. The samples were treated in air.

The conditions of pretreatment as so as conditions of application of silver on polymers were optimised on basis of preliminary experiments.

The sorption of nanoparticles were evaluated by following methods:

UV-VIS spectroscopy – was used for measuring of size of nanoparticles (shift of maximum of absorption) and for determination of concetration.

LIBS – amount of silver sorbed on material from liquid.

EDS – distribution of silver nanoparticles on surface.

It can be arisen from this study, that plasma pretreatment of polymeric materials increases sorption of silver nanoparticles on material. This effect can be used for preparation of composite structures with high amount of silver nanoparticles. This observing conform to hypothesis that increasing of roughness of surface of polymer and increasing of polarity of this surface lead to higher sorption of metal nanoparticles.

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S4 Temperature Dependence and Isotopic Effect in Recombination of HCO^+ and DCO^+ Ions

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The triatomic ions H_3^+ and HCO^+ play central roles in the chemical kinetics of interstellar gas clouds. The ion HCO^+ and its isomer HOC^+ were observed many times in interstellar medium. The major destruction mechanism of HCO^+ is dissociative recombination. Theory of disociative recombination can describe triatomic ions only in cases where a neutral dissociative state crosses the ionic Born-Oppenheimer surface in the Franck-Condon region; in these cases the recombination is fast. Ions H_3^+, D_3^+, and also HCO^+ do not have favorable 'curve crossing'. Recently by inclusion of non-Born-Oppenheimer Jahn-Teller coupling the calculations were made for recombination of H_3^+ and D_3^+ ions. The results agree with data obtained in recent experiments. Only very recently the same sort of calculations was made also for HCO^+. The calculated data are in disagreement with recent experimental data. In order to solve the discrepancy we used well-defined conditions in Flowing Afterglow experiment (FALP) to remeasure recombination rate coefficients of HCO^+ and DCO^+ ions and their temperature dependencies. In FALP the decay of the HCO^+ (or DCO^+) dominated plasma along the Flow tube is monitored by a Langmuir probe. The measurements were carried out at different temperatures and at different densities of the reactants to exclude influence of the ion formation, ion excitation and presence of high-energy isomers HOC^+ (or DOC^+), which are quenched in reactions with H_2 (or D_2). The measured values of recombination rate coefficient of HCO^+ ion are in very good agreement with majority of previous experimental results. We did not obtain agreement with recent calculations. The calculated rate coefficients are in low temperature region at least 10 times lower than our experimental data. At low temperature our results for HCO^+ and for DCO^+ are in contradiction with recent Flowing Afterglow studies.

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S4 Absolute Density of N Atoms Produced by Dielectric Barrier Atmospheric Discharge

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The atmospheric pressure discharges are currently in the focus of scientific and industrial interest. Among the active particles produced by the molecular plasmas, the atoms play a prominent role. As a consequence, there is an increased need for reliable diagnostics method suitable for the atmospheric plasmas. The most valuable are those providing the quantitative

data. Many techniques developed for low pressure plasma diagnostics such as chemical titration, laser induced fluorescence, two photon absorption laser induced fluorescence and mass spectroscopy etc. are difficult to carry out at higher pressures.

Several investigators successfully used the electron paramagnetic resonance (EPR) spectroscopy for a low pressure plasma diagnostics. This technique is based on the resonant absorption of microwave photons by the electron transitions between Zeeman split energy levels. The main advantage is the use of the ground level for the absorption measurement. Every atom or molecule with a non-zero magnetic momentum (i.e. paramagnetic) has a typical EPR spectrum. From the quantum mechanical calculations it can be shown that the EPR lines of some species are not pressure broadened, which should permit the measurement at atmospheric pressure. A typical example is the atomic nitrogen. In this paper we tested the suitability of the EPR method for the atomic nitrogen detection and quantitative measurement at atmospheric pressure. We used a commercially produced plasma source based on dielectric barrier discharge for our tests. However the proposed method is usable with any atmospheric plasma source.

The experiment was carried out in a flow regime. The mixture of N_2-O_2 gases passed through the coaxial dielectric barrier discharge to a quartz afterglow tube. The N atom density was measured 20 cm downstream from the active discharge by means of EPR. After the calibration by molecular oxygen we obtained the absolute concentration of atomic nitrogen.

In authors' best knowledge it is the first attempt to measure the absolute concentration of N atoms at atmospheric pressure by means of EPR.

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S4 Diffuse Coplanar Surface Barrier Discharge as Effective Atmospheric-Pressure Plasma Source for Permanent Hydrophilization of PP Nonwovens Carried out in Ambient Air

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The Diffuse Coplanar Surface Barrier Discharge (DCSBD) plasma has unique properties, which clearly differentiate DCSBD from other atmospheric-pressure plasma sources. Its primary feature is ability to generate a thin layer of macroscopically uniform diffuse plasma due to special design and optimalisation of the electrode geometry. The apparent advantage of DCSBD comparing e.g. to the APGD, which tends to degenerate into a macroscopically inhomogeneous volume DBD with stationary microfilaments when the discharge power is increased, is that increasing the discharge power tends to increase homogeneity of DCSBD. DCSBD generates a thin uniform plasma layer with the high power density (100 W/cm^3) in any working gas without any admixture of rare gases. Due to temperature non-equilibrium, plasma generated by DCSBD is suitable for hydrophilic surface treatment of materials such

as nonwoven fabrics, which can be done only at temperatures near the room temperature to avoid the destruction of treated material.

Briefly discussed DCSBD is a heart of our prototype of an atmospheric-pressure narrow web plasma treater ZUP 200. This device technically and economically outperforms the existing atmospheric-pressure plasma textile treaters, and can be easily scaled-up and integrated into existing continuous manufacturing systems. The unique performance characteristics of our plasma treater are illustrated by results on ambient air-plasma hydrophilization of light-weight spun-bonded polypropylene nonwoven fabric, where the permanent hydrophilization was obtained at power consumption less than 1 kWh/kg.

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S4 Electrical and Optical Properties of Diffuse Coplanar Surface Barrier Discharge

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Atmospheric-pressure, non-equilibrium plasmas produced by dielectric barrier discharges (DBD) are very attractive for various industrial applications (pollution control, sterilization, ozone generation and surface modification) because of their low-cost, high operation speed and ability to operate without vacuum systems. Unique type of DBD generator, so called Diffuse Coplanar Surface Barrier Discharge (DCSBD), is able to produce a thin layer of non-equilibrium plasma with high power density (up to 100 W/cm^3) in practically any working gas (even in pure oxygen). Comparing to other surface DBD setups (as e.g. that invented by Masuda et al.), major advantage of the DCSBD is that surface micro-discharges are in no contact with metallic electrodes. The DCSBD is therefore conveniently utilised for surface treatment of wide scale of materials (e.g. polypropylene non-woven fabrics, polyester cords, wood and glass).

In this work the basic electrical and optical properties of DCSBD were investigated. The discharge was powered by AC high voltage and electrical measurements were performed using a digitizing oscilloscope Tektronix TDS 2024 (bandwidth 200 MHz, up to 2 GS/s), a Tektronix P6015A high voltage divider probe (1:1000, bandwidth 50 MHz) and Pearson Electronic current monitor model 4100. Optical measurements were performed by Avantes 2048TEC. The discharge power and vibrational temperature of plasma were calculated for working gases consisting of various ratios of nitrogen and oxygen.

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S7 Numerical Study of the Density Ratio Effect on Propagation of a Cloud of Hot Electrons

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A study is made of the formation of the spectra of Langmuir waves excited as a result of the development of beam-plasma instability in collisionless plasma with low-frequency turbulence. The effects of density ratio on evolution of propagation of beam and excited Lnagmiur waves is investigated in one dimensional solar corona plasma with numerical calculations of quasilinear equations. We performed numerical computations of the beam dynamics for a wide range of initial beam number density. It is found that the character of the stream diffusion and of the plasma turbulence growth greatly depend on the stream density. Results of numerical simulations show that the electron distribution function relaxes to a plateau state and evolution of the height of the plateau is investigated and the dependence of these results on the stream density is obtained.

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S7 Surface Plasma Wave Excitation over a Plasma Cylinder

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A relativistic electron beam propagating in a plasma cylinder excites a surface plasma wave via Cerenkov interaction. An electron beam of velocity v_{0b} and density n_{0b} is launched into the plasma of density n_p. For a thin plasma cylinder, the SPW field extends to the axial region and strong coupling with the beam occurs. The growth rate of the surface plasma wave, initially increases with frequency ω, attains a maximum and then falls off. For the plasma radius of few nanometer, the study is relevant to surface plasmons excitation and their propagation along nanowires.