TREATMENT OF LIQUIDS BY WARM PLASMA WITH VORTEX EFFECT

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This paper describes the design, construction and operation of a reactor where an atmospheric pressure warm plasma discharge is applied to the treatment of dynamic liquids created by a vortex effect. A high-frequency resonant converter is used as plasma source in the range $35-43\,\mathrm{kHz}$ and $0.4-0.6\,\mathrm{kW}$.

As application, a liquid scintillation cocktail treatment is reported. The reactor can also be applied to the treatment of organic liquids considered as toxic wastes. Mass spectra is used todemonstrate the cracking of organic molecules and hydrogen production considered as one of the most significant energy sources; because hydrogen can be renewable and environ-mentally safe.

MODELING NON-LOCAL THERMODYNAMIC EQUILIBRIUM PLASMA USING THE FLEXIBLE ATOMIC CODE DATA

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In this paper, we introduce our computer model, radiative-collisional code based on the flexible atomic code (RCF), for calculations of the properties of photoionized plasmas. RCF uses database generated by the flexible atomic code. Using RCF it is shown that incorporating the satellite lines from doubly excited Li-like ions into the He_α triplet lines is necessary for reliable analysis of observational spectra from astrophysical objects.

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THE CALCULATIONS OF ION TRAJECTORIES AT MAGNETOPLASMA SEPARATION AND EXPERIMENTS WITH POLYATOMIC GASES

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Calculated trajectories of ions with different masses, coinciding with experiment conditions and indicating the possibility of mixture separation, are obtained. Experiments for plasma Ar, N_2, CO_2, simulating spent nuclear fuel, upon combination of pulsed discharge with a stationary one with incandescent cathode are carried out. The oscillo-grams of discharge current and voltage at low emission currents and constant energy input show that the maximum current by time is at the third of the maximum voltage, thus further increasing of voltage does not result in a larger number of charged particles, and the energy is spent on other processes. With an increase of emission current the nonlinear character of the discharge current and voltage, which may be indicative of the role of dissociation and vibrational levels in energy consumption, is observed. In addition, there is connection between number of atoms in molecule and the values of maximum discharge current and pressure of injected gas.

MODELING OF HIGH-POWER PULSED PLASMA DISCHARGES FOR THIN FILM DEPOSITION

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High-Power Impulse Magnetron Sputtering (HiPIMS) is a promising thin film deposition technique. However, the physical mechanisms operating in the HiPIMS plasma are still far from being completely understood. This issue is even more pronounced when adding reactive gases, which lead to loss of process stability, reduced deposition rates, as well as generation of detrimental energetic negative ions. In this contribution we try to tackle these challenges through computational modeling benchmarked with experiments. The aim is to understand the interaction between the physical and chemical mechanisms that operate in the bulk plasma and the coupling with surface reactions. A new time-dependent plasma chemical model for reactive HiPIMS called R-IRM has been developed. As a first case study we explore the influence of oxygen dilution on the discharge properties, such as electron density, the ionization fraction of the sputtered vapor, and the oxygen dissociation fraction.

This research has been supported by the CNRS, France.

ELECTRICAL BREAKDOWN AND ELECTRON TRANSPORT IN SYNTHETIC AIR

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The talk reviews recent experimental and simulation activities concerning electron transport and kinetics in synthetic air, under the effect of steady and alternating electric fields. The transport characteristics, in particular, the drift velocity has been measured in a novel scanning drift tube apparatus that allows recording of the spatio-temporal development of electron swarms in a steady electric field. The electron kinetics and its relation to the breakdown of the gas have been investigated under steady and radio-frequency fields both experimentally and via particle-based simulations. The frequency dependence of the breakdown voltage conveyed information about the importance of volume vs. surface processes in the gas breakdown. The experimental observations are supported by simulation studies that provide an in-depth understanding of the investigated phenomena.

This research has been supported by the OTKA Grant K-105476.

ON RECENT PROGRESS IN STUDYING CHEMICAL PHENOMENA AND SURFACE INTERACTIONS IN PLASMAS USING INFRARED ABSORPTION TECHNIQUES

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Chemical sensing using mid infrared laser absorption spectroscopy (MIR-LAS) in the molecular fingerprint region from 3 to 20 μm, which contains strong ro vibrational absorption features of a large variety of gaseous species, has been established as a powerful in situ diagnostic tool for molecular plasmas. Quantum cascade lasers (QCL) in particular have become the infrared light sources of choice for plasma diagnostics in the mid infrared. MIR-LAS provide a means of detecting stable and transient molecular species in ground and excited states and of measuring the concentrations and temperatures of reactive species in plasmas. The present contribution reviews modern trends specifically in the rapidly changing field of plasma spectroscopy. Special attention is devoted to in-situ studies of plasma chemistry and reaction kinetics in gas discharges and on selected aspects of plasma surface interactions. A link is thereby provided to modelling of plasmas and surface phenomena.

PLASMA INSTABILITIES: THE INFLUENCE ON PLASMA INSTABILITIES DURING THE SOLID-PLASMA PHASE TRANSITION

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Improving our knowledge on the onset of plasma instabilities is important not only for the fundamental plasma physics but also for the understanding of high-energy-density plasmas, inertial confinement fusion as well as for the progress in the development of intense photon and particle sources. For instance, in the direct drive concept of fusion using lasers, where the laser energy is delivered to the outer layer of the target, the growth of plasma instabilities from the first moments of plasma generation will strongly affect the heated outer layer of the target and as a result, it will affect the explosion as well as the implosion phase of the plasma. Furthermore, in dense plasmas generated by pulsed power devices such as Z-pinch, X-pinch or other wire array configurations, the generation and growth of plasma instabilities determines the overall plasma dynamics. Plasma instabilities have been studied extensively both experimentally and theoretically over the last decades (Haines Plasma Phys. Control. Fusion 53 (2011) 093001). In most attempts, this has occurred by investigating the generation and growth of the instabilities deliberating the target material as plasma from the very beginning of the interaction with the energy source (e.g., the fast rising current generated by a pulsed power Z-pinch device). In this work, we are attempting to investigate the role and the influence of the thermoelastic regime of the solid material on the generation and the dynamics of the plasma instabilities.

The authors acknowledge financial support through the Action "National Research Infrastructure for HiPER" MIS 376841 (co-funded by the European Union and Hellenic National funds within the Operational Programme "Competitiveness and Entrepreneurship"). The 3-D MHD simulations were performed with the use of the code PLUTO. The work has been performed at the research facilities of the Centre for Plasma Physics & Lasers of TEI of Crete.

DOMINANT PHYSICOCHEMICAL PROPERTIES OF SF_6/N_2 THERMAL PLASMAS WITH A TWO-TEMPERATURE CHEMICAL KINETIC MODEL

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It's increasingly clear that the existence of thermodynamic equilibrium is an exception rather than the role in SF_6/N_2 thermal plasmas. we intended to investigate the dominant physicochemical properties of SF_6/N_2 thermal plasmas at atmospheric pressure from 12000 K to 1000 K with considering the thermal non-equilibrium. A two-temperature chemical kinetic model containing all the available reactions is developed. The temperature difference between the electron and the heavy species is defined as a function of the electron number density. The molar fractions of species are compared to the equilibrium composition predicted by Gibbs free energy minimization. By analyzing the main reactions in the generation and loss of a dominant species, the chemistry set is simplified and characterized by a few species and reactions. Then, the dominant physicochemical properties are captured and the computing time of complicated chemical kinetic model is dramatically shortened at the same time.

UNDERSTANDING THE LONG-LIVED, PULSED, RF-DRIVEN, ULTRA-HIGH PURITY HYDROGEN PLASMA THAT IS DRIVING THE 1.4 MW SNS NEUTRON SCATTERING FACILITY

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60 Hz, 1 ms long, 50 kW RF pulses produce hydrogen plasma that delivers 1 ms long pulses of ~ 60 mA H^- ions to our linear accelerator. After being accelerated to ~ 1 GeV the ions are stacked in a proton accumulator ring. After 1 ms, the protons are expelled in less than 1 μs and directed to a Hg target where they liberate large quantities of neutrons, which are used for neutron scattering studies. The H^- production is enhanced with a few mg of Cs that are applied after 3 hours of conditioning and last at least 51 days during which ~ 4 amp-hours of H^- are delivered, an unprecedented quantity for pulsed accelerator H^- sources. The conditioning removes all impurities because their heavy masses sputter Cs and cause performance decay. Our low plasma potential renders the light hydrogen ions unable to sputter the Cs enabling unprecedented lifetimes. The ultrapure hydrogen plasma has very high breakdown voltages that require special measures for ignition, such as continuous low-power plasma

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HYBRID ELECTRON BEAM TECHNOLOGY FOR HIGH CONCENTRATIONS NO_x AND SO_2 REMOVAL FROM OFF-GASES

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High concentrations of SO_2 and NO_x are released into the atmosphere from off-gases generated from many industrial processes. These two pollutants are very harmful to human health and the environment. The aim of this research is to study hybrid Electron Beam (EB) technology coupled with the wet scrubbing method. Our results show that the NOx removal efficiency (NO inlet concentration being 1500 ppm) increases from 5% (EB only) to around 50% with use of hybrid technology even when the irradiation dose is as low as 6.5 kGy. Similar results are achieved for the removal of SO_2, where the removal efficiency of SO_2 increases from around 20% (EB only) to 74% with the use of the hybrid technology for the inlet concentration of SO_2 being 1000 ppm at the absorbed dose of 10.9 kGy. The hybrid EB process reduces the energy consumption of SO_2 and NO_x removal by absorbing their oxidation products from the gas phase into the wet scrubber thus improving their removal efficiency in the gas phase.

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ENERGY FLUX MEASUREMENTS DURING DC- AND HIPIMS SPUTTERING OF COPPER

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The integral energy influx in a high power impulse magnetron sputtering (HiPIMS) discharge as well as in a conventional direct current magnetron sputtering (DCMS) discharge under same conditions (argon pressure of 0.5 Pa and discharge power of 100 W) has been determined using a passive thermal probe (PTP) (Stahl, M., Trottenberg, T., Kersten, H., Rev. Sci. Instr. 81(2010), 023504; Lundin, D., Stahl, M., Kersten, H., Helmersson,

U., J. Phys. D: Appl. Phys. 42(2009), 185202.). The probe can be regarded as a substrate dummy, with a sensitivity of less than 1 mW/cm^2. The energy influx was measured in radial direction (parallel to the copper target surface) as well as in axial direction (perpendicular to the target) at different positions. Furthermore, for selected positions the energy influx for different angular orientation of the probe and for various bias voltages of the PTP has been obtained experimentally.

It was found that the substrate heating is reduced in the HiPIMS process (70%) compared with the DCMS operating mode (100%) at the same average power. On the other hand, the energy flux per deposited particle is higher for HiPIMS (140%) compared to DCMS (100%), when taking the lower deposition rate (50%) for pulsed sputtering inot account. This is most likely due to the highly energetic species present in the HiPIMS plasma affecting the thin film properties remarkably (Lundin, D., Larsson, P., Wallin, E., Lattemann, M., Brenning, N., Helmersson, U., PSST 17(2008), 035021).

The dependence of the energy influx from the bias voltage of the substrate (e.g. PTP) is completely different for the ion component (at negative probe voltage) and the electron component (at positive probe voltage) and can be explained similar to typical Langmuir probe characteristics (Bornholdt, S., Kersten, H., Eur. Phys. J. D 67(2013), 176-187).

Finally, the comparison between experimental results and theoretical calculations on energy flux (Kersten, H., Deutsch, H., Steffen, H., Kroesen, G.M.W., Hippler, R., Vacuum 63(2001), 385-431) of charged species shows a good agreement.

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SURFACES WITH ROUGHNESS GRADIENT AND INVARIANT SURFACE CHEMISTRY FOR BIOLOGICAL APPLICATIONS

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Surfaces whose properties change gradually along the sample length, so-called gradient surfaces, are highly interesting for fundamental studies focused on the interaction between biomolecules or cells and surfaces. In our study, we investigate simple, vacuum-based strategy for fabrication of surfaces with gradient nanoroughness and wettability. This approach is based on the application of gas aggregation source of nanoparticles (Ti, Ag), combined with the magnetron sputtering of PTFE or PE-CVD deposition of C:H plasma polymer. It is shown that proposed strategy makes it possible to produce coatings with invariant surface chemistry, but with gradient roughness and wettability gradient from hydrophobic to super-hydrophobic.

Preliminary biological tests indicated that this leads to the spatial gradient in bacteria attachment and growth on the surface.

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FLEXIBLE HARD Ti-BASED NITRIDES FILMS WITH ENHANCED RESISTANCE TO CRACKING

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The paper reports on the texture and mechanical properties of magnetron sputtered Ti(Al,V)N and Ti(Ni)N films and their resistance to cracking. The films were reactively sputtered in a mixture of Ar+N$_2$ gases using DC magnetron. The texture, structure, macro-stress, mechanical properties of the films and theirs resistance to cracking in bending were characterized by (i) XRD, (ii) SEM, (iii) the Fisherscope H100 (iv) the indentation and bending test, respectively. It was found that: (1) the texture of sputtered Ti-based nitride films depends on energy $E_{bi} \approx U_s \times i_s / a_D$ delivered to the film by bombarding ions, here is Us the substrate bias, is the substrate current density and aDthe deposition rate and (2) the Ti(Al,V)N and Ti(Ni)N films with enhanced resistance to cracking are composed of TiN(220) and TiN(111), have dense voids-free microstructure and exhibits high ratio $H/E^* > 0.1$, high elastic recovery $We > 65\%$, compressive macrostress ($\sigma < 0$ GPa).

INVESTIGATION OF HARD Ag/A-C:H NANOCOMPOSITE COATINGS PRODUCED BY PECVD AND GAS AGGREGATION SOURCE OF NANOPARTICLES

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Hard Ag/a-C:H coatings were fabricated by novel technique that combines PECVD of a-C:H matrix with Gas Aggregation Source of Ag nanoparticles. This approach allows decoupling formation of NPs from the matrix deposition and thus provides almost independent control of the matrix properties and amount and size of embedded Ag NPs. Indentation measurements showed that complex modulus of the matrix is 120 GPa. Worsening of the mechanical properties was observed with increasing amountof Ag NPs in the film. Hence, to assure good mechanical properties of produced nanocomposites, Ag/a-C:H films with Ag content below 3% were selected for further studies. XPS revealed that such coatings have surface concentration of silver below 1%. The surface concentration of Ag may be enhanced by additional treatment of samples either by low pressure O_2 or N_2 plasma or by Ar atmospheric plasma jet that was found to effectively uncover NPs initially buried beneath the a-C:H surface.

This research has been supported by the project GA UK 1926314 and the grant SVV-2016.

REACTIVE HIGH-POWER IMPULSE MAGNETRON SPUTTERING OF Hf-O-N FILMS WITH TUNABLE COMPOSITION AND PROPERTIES

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High-power impulse magnetron sputtering with a pulsed reactive gas flow control was used for reactive depositions of Hf-O-N films. The depositions were performed using a strongly unbalanced magnetron with a planar hafnium target of 100 mm diameter in argon-oxygen-nitrogen gas mixtures at the argon pressure of 2 Pa. The nitrogen fractions in the reactive gas flow were in the range from 0 to 100%. The repetition frequency was 500 Hz at a fixed deposition-averaged target power density of 30 Wcm^{-2} with the duty cycle of 10%. The substrate temperatures were less than 140 °C during the depositions of films on a floating substrate. A pulsed reactive gas (O_2 and N_2) flow control made it possible to produce high-quality Hf-O-N films of various elemental compositions with high deposition rates of $175 - 240$ nm/min. We present the gradual change of hard (18 GPa), highly optically transparent and hydrophobic HfO2 films into harder (25 GPa), opaque and more hydrophobic HfN films.

MODELING OF PARTICLE FORMATION DURING INTERNAL ARCING

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A numerical model is developed to represent the formation of metal particles during internal arcing in enclosures. The model presented here is a combination of a population balance model for metal particles together with a MHD plasma model for air-metal mixtures. The model is based on Navier-Stokes equations for flow dynamics, Maxwell equations for electric and magnetic field, radiative transfer equation considering air-metal vapor mixtures and metal particles, and the Method of Moments (MoM) for metal particles homogeneous nucleation and growth by heterogeneous condensation and coagulation. Numerical investigation by means of simplified geometries demonstrates the strong influence of metal particles on radiation and heat balance with consequent pressure rise due to enhanced absorption of radiation.

STUDY OF ARC PLASMA DYNAMIC BEHAVIOUR USING COMBINATION OF FAST IMAGING AND MAGNETIC DIAGNOSTICS

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We have devised a novel experiment on a dc (25 kW) non-transferred plasma torch with a combination of magnetic and fast imaging diagnostics. The magnetic probes are incorporated inside the anode cooling channel away from the plasma but able to detect fluctuating magnetic fields generated due to the movement of the arc root and return currents in the anode material. Simultaneously, end-on imaging is carried out using a high speed camera of frame rate approx. 10^5 fps. . The experiments are carried out for nitrogen gas flow rates (20 to 60 lpm) in the presence of external magnetic field (100 to 500 G) for various currents (70 to 120 A) at 1 atm. Imaging clearly yields the arc root rotational velocity due to $\mathbf{J} \times \mathbf{B}$ force, and nature of the arc root attachment such as constricted, multiple attachments or diffused. The magnetic diagnostics also reveals the arc root rotational velocity, shows good agreement with imaging and the effect of the discharge current is very evident.

NET EMISSION COEFFICIENT OF MIXTURES CARBON-HELIUM-COBALT/YTTRIUM/NICKEL THERMAL PLASMAS

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The net emission coefficient (NEC) of He−C−Co/Yt/Ni mixtures have been calculated under the assumption of a local thermodynamic equilibrium at different pressure values and in the temperature range between 1000 and 20 000 K. In this study we took into account the emission radiation resulting from the atomic continuum, the molecular continuum, the atomic lines and some molecular bands. Free-free transitions (Bremsstrahlung) and free-bound (electron-ion recombination and electron attachment) have been considered for the calculation of atomic continuum. For Bound-bound transitions, natural, resonance, Van der Waals, Stark and Doppler effects have been taken into account in the calculation of the lines broadenings. The self-absorption of the resonance lines have been treated using the escape factors. Molecular emission has been only considered for C_2 molecule.

ANALYSIS OF THE INTENSIVELY BLASTED ELECTRIC ARC INSIDE THE ARC HEATER'S ANODE CHANNEL

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The contribution deals with the model of the intensively blasted electric arc in an arc heater's cylindrical anode channel. Real measured data (current, voltage, gas flow rate, power loss) serve as input data and characterize the operation of the arc heater, while calculations reveal parameters of the arc (radius, temperature and voltage axial distribution). Benefiting from years of experience in experiments and modeling, the authors have designed an updated model which enables to exclude the influence of near-electrode regions. The complex model exploits more precise first estimations of the cathode and especially of the anode voltage drops determined from the measured data, and refines them during iterative computations. As examples, two data sets (for different argon flow rates) are analyzed. The results show the independence of the cathode voltage drop on the gas flow rate and an opposite character of the dependence of the cathode and anode voltage drop on the arc current.

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CFD SIMULATION AND WEIBULL ANALYSIS OF DIELECTRIC RECOVERY IN A SF_6 SELF-BLAST INTERRUPTER

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The design and development procedures of SF_6 gas circuit breakers are still largely based on trial and error through testing although the development costs go higher every year. The computation cannot cover all the physics happened inside the breakers, however, the knowledge of arc behavior and its capability inside a SF_6 self-blast interrupter by numerical analysis should be useful for investigating the interrupter. In this paper, in order to get further information into the interruption process of a SF_6 self-blast interrupter, gas flow simulations with a CFD-arc modeling are performed during the whole switching process such as high-current period, pre-current zero period, and current-zero period. Through the complete work, the temperature of residual arcs as well as the breakdown index parameterized by Weibull distribution after current zero can be a good criterion to predict the dielectric capability of interrupters.

DENSITY MEASUREMENT IN SPACE PLASMA BY MUTUAL IMPEDANCE TECHNIQUE: MIME INSTRUMENT ON "JUpiter ICy moons Explorer" (ESA/JUICE mission)

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Mutual Impedance Measurements, MIME, instrument is a part of the Radio Wave Plasma Investigation, RPWI, consortium which has been selected by European Space Agency, ESA, on the nest planetary JUICE mission. Impedance probes, which are well known in geophysical prospection, in particular for ground permittivity investigations, have been successfully transposed to space plasmas. Transmitting and receiving electrodes are used for measuring on open circuit the dynamic impedance of the system at several fixed frequencies over a range that includes characteristic frequencies of the ambient plasma. The measurements are then interpreted using a suitable theory and the values of plasma parameters, such as the electron density, temperature can be deduced. Some example from Rosetta mission will be presented. The MIME proposal is then described and its ability to make valuable measurements in the Jupiter space environment, and in particular round Callisto and Ganymede is investigated.

This research has been supported by the National French Space Agency (CNES).

INVESTIGATION OF ATMOSPHERIC PRESSURE ARC DISCHARGE IN AIR BASED ON CHANGES IN LASER BEAM PROPAGATION

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Investigation of plasmas using bending of laser beam can reveal e.g. information about electron density as was demonstrated for free-burning argon atmospheric pressure arc discharge (APAD) (Schreiber et al., Plasma Physics 15.7 (1973) 635). Laser deflectometry can be also used to estimate gradients of neutral gas temperature in atmospheric pressure plasmas and in their surroundings. Recently, bending laser beam method named laser schlieren deflectometry was tested for estimation of neutral gas temperature in the case of filamentary non-thermal atmospheric pressure plasma jet (Schäfer et al., Rev. Sci. Instrum. 83.10 (2012): 103506). The main goal of this work is to extend laser deflectometry studies for the case of thermal discharges and obtain spatially resolved information about stable/unstable APAD using 1D scanning of the laser beam. Advantages and limitations of laser deflectometry as a diagnostic tool for the case of APAD are discussed.

This research has been supported by the DFG Transregio 24 “Fundamentals of Complex Plasmas”.

NUMERICAL STUDY OF WOOD GASIFICATION PROCESS IN THERMAL PLASMA REACTOR

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A numerical study of gasification processes of crushed wood as a model substance of biomass in thermal plasma reactor heated by hybrid water-argon plasma torch was carried out. The model of the gasification represented by heterogeneous reacting system in thermodynamic equilibrium taking into consideration high number individual substances predicts production of solid carbon at temperatures up to 1000 K. However, a simplified reaction scheme of syngas production driven by kinetics represented by two homogeneous non-reversible chemical reaction as adopted in a numerical model showed the proportion of CO and H_2 at the exit close to the experimental values. To investigate the process of gasification in detail with possible impact on performance, the numerical model using this simplified chemical reaction scheme has been created using ANSYS-FLUENT program package and the numerical results obtained for three different particles diameters were compared with the experiment.

This research has been supported by the Czech Science Foundation under grant project No. 15-19444S.

EFFECT OF PLASMA DRIFT IN DUAL MAGNETRON ON DEPOSITION PROCESS

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Magnetic field of the dual magnetron plays an important role in plasma generation and depending on the configuration of magnetic field lines it is possible to form asymmetric magnetic field line distribution which is responsible for formation of so called plasma drift in dual magnetron. This phenomenon causes deflection of plasma to one side. In this study we focus on the detailed investigation of the effect of plasma drift on the deposition process and on the thin films formation. It will be shown that the higher is the asymmetry in magnetic field configuration the more pronounced is the plasma drift effect. Through the measurements of spatial distribution of the deposition rate at the substrate holder position we observed an asymmetry also in the deposition rate. By the analysis of the discharge properties we suggested this asymmetry is caused by the ambipolar diffusion of the drifting ions.

DECOMPOSITION OF VOLATILE ORGANIC COMPOUNDS USING DIELECTRIC BARRIER DISCHARGE PLASMA REACTOR

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Applicability of the nonthermal plasma reactor for the decomposition of volatile organic compounds (VOCs) is tested on the example of toluene vapors in the air at room temperature and atmospheric pressure. Plasma reactor with dielectric barrier discharges (DBD) is supplied from a pulse modulated power supply. The frequency of the modulation pulse during the experiment is in the range from 600 Hz to 1 kHz. The waveform of discharge voltage without the modulation is continuous sine form with a frequency of 15 kHz. Catalyst-hybrid plasma system is also investigated to compare both methods of hydrocarbons conversion. Removal efficiency and energy yield of the decomposition process are given for different ways of toluene removing. Ozone and byproducts concentrations are also measured and analyzed.

This research has been supported by the The work was carried out as a statutory project, supported by a Ministry of Science and Higher Education, Warsaw, Poland.

STUDY OF THE EFFECT OF LOW-TEMPERATURE PLASMA EXPOSURE ON MOULD FUNGI COLONIZING PAPER

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The effect of low-temperature plasma of low-pressure and atmospheric pressure gas discharges on viability and biological properties of mould fungi belonging to the genus Aspergillushas been studied. Spores of *A. niger* and *A. versicolor* were germinated on the surface of paper specimens. It was shown that mycelium was more sensitive to cold plasma treatment than spores, though both studied fungi showed a significant tolerance to plasma impact. Plasma treatment of mycelium for 5 minutes had almost no effect on the survival of fungi. Only the increasing of the exposure time up to 20 minutes resulted in reduction the number of colony-forming units (CFU) of mycelium by $2-3$ orders, while the number of viable spores decreased only in $3-15$ times. It was found that all investigated *A. niger* colonies grown from survived CFU remain the ability to produce a significant amount of organic acids.

This research has been supported by the Belarusian Republican Foundation for Fundamental Research (grant No. T15MC-050).

HIGH-POWER PULSED NON-THERMAL OXIDANT PLASMA — PERFECT TOOL FOR ENERGY-EFFICIENT MICROBIOLOGICAL DECONTAMINATION

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Microbiological decontamination is a challenging issue for “homo urbanus”. Because of the frequent necessity to be applied to large spaces (or quantities of products), it should be ecologically friendly and energy-efficient. There has been elaborated thermodynamic approach for the optimization of microbiological decontamination. Chemical oxidation by atomic oxygen should be ensured for decontamination.

Optimal conditions for the reliable energy-efficient sterilization can be achieved in microwave non-thermal plasma. Microwave discharge plasma is electrodless and can be easily maintained even inside of the dielectric package. High-power microwave pulses (at a sufficiently high duty ratio — the average power remaining small) guarantee energy-efficient dense plasma generation even at atmospheric pressure. Optimal plasma parameters for decontamination can be controlled through the amplitude, duration and duty ratio of microwave impulses.

GRAPHENE PRODUCTION AND FUNCTIONALIZATION USING PLASMA-BASED METHODS

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A microwave atmospheric plasma driven by surface waves has been used to synthesize free-standing graphene sheets. Carbonaceous precursors are injected into the plasma, where decomposition processes take place. The transport of plasma generated gas-phase carbon atoms and molecules into colder zones of plasma reactor results in nuclei formation. The main part of the solid carbon is gradually withdrawn from the "hot" region in the outlet plasma stream where nanostructures assemble and grow. Subsequently, the collected graphene sheets were transferred to different types of substrates and functionalized by capacitively coupled N_2 plasma. The samples were treated with low input power at different exposure times and different positions, while maintaining 0.1 mbar pressure. The synthesized nanostructures were characterized by SEM, Raman spectroscopy and contact angle measurements.Plasma characterization was performed by mass and optical emission spectroscopy.

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EFFECT OF INITIAL PARTICLE VELOCITY ON ENERGETIC CHARACTERISTICS IN PLASMA SPRAY

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The one-dimensional model of the particle acceleration and heating was applied for the study of particle energetic characteristics in plasma spraying process. The effect of the particle diameter and initial velocity on the particle's thermal and kinetic energy at the moment of collision with substrate was studied. The particle thermal properties were taken from data for Yttria-Stabilized Zirconia. Considering the constraints applied to the model it is shown that an increase in the initial velocity of a particle injected into plasma jet significantly reduces the temperature, which, in its turn, determines the total (kinetic and thermal) energy of particle. The minimal total energy is attained when particle velocity is compared with the plasma jet velocity. After this point the total energy begins to grow slowly and the particle's kinetic energy becomes lined up to the thermal one (in the case of the small diameter particles) or even exceeded (for particles with larger diameter).

EFFECT OF THE PLASMA TREATMENT OF HYDROTALCITE-TYPE CATALYST

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The aim of this work was to study influence of the plasma treatment on hydrotalcite-type catalyst properties. Development of new catalysts for the petrochemical industry has high potential primarily in the field of extraction products from the biomass resources. Nonthermal atmospheric pressure dielectric barrier discharge (DBD) under defined conditions has been used for modification of catalysts. Hydrotalcites with Mg/Al molar ratio 3:1 were prepared by coprecipitation. Catalysts were used either without treatment or after calcination or with subsequent plasma modification for both cases. Characterization of the catalysts was performed by techniques XPS, SEM, XRD, XRF and BET. Catalytic activity was tested using aldol condensation of furfural and acetone. The investigated catalysts showed different catalytic performance and the best catalyst was uncalcined plasma treated hydrotalcit.

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IMPACT OF OPEN DENSITY OF DOUBLE PATTERNING ON GATE PROFILE CONTROL IN CL_2-BASED PLASMA ETCHING

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The method of double patterning in gate etching utilizes line and cut masks. Actual pattern-area in Poly-Si etching by double patterning is the union of line and cut masks due to overlapped area of them. Different open density provides different concentration of etchants to Poly-Si to be etched, which leads to necking and bowing profile of gate. In this paper, a Cl_2-based plasma in gate etching is chosen as the control knob for vertical gate. Our strategy is to expect optimal Cl2 content for vertical gate with various of products. In this paper, open densities of 4 products are extracted, which are 81.3%, 78.1%, 73.5% and 68.8%. When gates of 4 products are patterned with a same Cl_2 content, they have -0.5 nm, 0 nm, 2 nm, 4 nm necking gate profile respectively. Narrower open density lets gate profile more necking. Necking rate is 0.37 nm/%. Experimentally, 40, 39, 36 and 34 sccm of Cl_2 content can make gate profile vertical, respectively. The formula for optimal Cl_2 content is 0.5 sccm/%.

HYDROLYSIS OF PLA-LIKE PLASMA POLYMER FILMS WITH VARYING DEGREE OF CROSSLINKING

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Poly-lactide acid (PLA) based biodegradable films are of interest for packaging materials or bioapplications.

Plasma-assisted vacuum evaporation technique uses oligomers released during thermal decomposition of source polymer as precursors for plasma polymerization. Conventionally prepared PLA with $m_w = 10000$ g/mol was used as a source polymer. Films were prepared at various RF (13.56 MHz) plasma powers (0âĂŞ20 W) in order to vary the amount of cross-linking in the film.

Swelling and hydrolysis of films were monitored in real time using spectroscopic ellipsometry. The concentration profile of products of hydrolysis was measured by liquid-chromatography (LC-MS). FTIR, XPS and SEM analyses were used for monitoring of film composition and surface characterization. Molecular weights of source polymer and of the plasma polymer were determined by gel-permeation chromatography (GPC). Possibility to prepare PLA-like plasma polymer films with controlled degradability by hydro-lysis was demonstrated.

REACTIVE HIGH-POWER IMPULSE MAGNETRON SPUTTERING OF THERMOCHROMIC VO_2 FILMS AT LOW SUBSTRATE TEMPERATURES

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High-power impulse magnetron sputtering with a pulsed reactive gas (oxygen) flow control was used for depositions of thermochromic VO_2 films (100 nm thick) onto floating Si substrates at the temperatures, T_s, of $250 - 400\,^{\circ}$C. The depositions were performed at the argon pressure of 1 Pa. The duty cycle was set to a constant value of 1% at the deposition-averaged target power density of $12 - 14\,\mathrm{Wcm}^{-2}$. The ellipsometric measurements were performed in the range of $300 - 2000$ nm and $25 - 100\,^{\circ}$C. The VO_2 films prepared at the voltage pulse duration of $80\,\mu$s exhibit very low room-temperature k (down to 0.11 at 550 nm; applies also to the lowest $T_s = 250\,^{\circ}$C), leading to a high predicted transmittance of the film on glass substrates in the visible region (e.g. up to 65% for a 100 nm thickness). The films exhibit a high infrared modulation, perfect reversibility of the thermochromic behavior and a lower transition temperature (48 °C) than the bulk VO_2 (68 °C).

PROGRESSIVE FIRE FIGHTING METHODS

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This article describes fire fighting experiments on the n-heptane flame pool with an electrically charged water mist generated by the low and medium-pressure nozzles in order to improve the fire-fighting efficiency. There is also a short piece of information about the influence of an applied voltage size, an electrode configuration, a water flow rate, a water pressure and water mist nozzles types. Higher extinguishing efficiency of electrically charged water mist fire fighting nozzles was confirmed with a shorter extinguishing time and consumed water. The benefits and practical usefulness is obvious: the faster and more efficient extinguishing of fire causes lower numbers of deaths and injuries and a smaller damage to the protected property.

This research has been supported by the grant SGS16/076/OHK3/1T/13.

EFFECT OF TREATMENT WITH SODIUM CHLORIDE SOLUTIONS LOW-TEMPERATURE PLASMA TO YIELD HYDROGEN PEROXIDE

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Based on the pilot study, which was created by a switching power supply for reactor diaphragm electric discharge, for the first time, the dependence of the output of hydrogen peroxide in the model solutions of sodium chloride on the amplitude of the voltage supplied to the pulse-discharge zone, the pulse duration, the model solution conductivity and power consumption. It is shown that the maximum effect of the disinfecting agent release occurs at a value of the water conductivity of 0.17 mS/cm, the applied voltage of 2.3 kV pulse amplitude and pulse width in the range of $4 - 8$ ms. It is proved that the overall yield of H_2O_2 is independent of the water flow rate through the reactor, and the correlation between the concentration of the product from the power input to the discharge has a linear increase in the range of $1900 - 2300$ V.

Ag/Al_xO_y NANOCOMPOSITES PREPARED BY MEANS OF GAS AGGREGATION CLUSTER SOURCE AND RF MAGNETRON SPUTTERING

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Silver based nanocomposites are due to their unique optical, electrical and bio-related properties widely used in different applications. In this study, silver nanoparticles (NPs) were prepared using gas aggregation cluster source and were embedded into Al_xO_y matrix deposited by RF magnetron sputtering of Al_2O_3 target in Ar atmosphere. Produced nanocomposites that had form of sandwich structures with alternating layers of Ag nano-particles and Al_xO_y matrix were studied from the point of view of their chemical composition, optical properties and morphology. It was found that Ag nanoparticles in produced nano-composites preserved their metallic character. Furthermore, Al_xO_y matrix dramatically increased temporal and thermal stability of embedded Ag NPs. In addition, preliminary antibacterial tests revealed strong antibacterial efficiency of such produced nanocomposites.

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SURFACE TREATMENT OF SPRING WHEAT SEEDS BY OZONE IN CONCENTRATION COMMON FOR ATMOSPHERIC PRESSURE GAS DISCHARGE

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There are a number of plasma treatment ways using surface dielectric barrier discharges, or plasma jets to effect surface biological contaminations (microbes, biofilms, or pathogenic fungi) which are based on ozone formation. Besides, ozone due to its powerful bactericidal action can turns out the main factor providing the positive effect especially in the case of decontamination of developed surfaces. Because to eliminate bio-contaminations in different curvatures of surface is rather difficult with the methods of direct action (ion or electron bombardment, UV-irradiation). These methods are essentially worse than the method of volume effect such as treatment by intense electro-magnetic fields, by liquid or gaseous substances.

The work presents the experimental results on pathogenic microflora elimination on spring wheat seeds (triticum aestium L) of 2013 and 2014 yield by ozone synthesized from humid air (1, 2 and 4 g/m^3) and oxygen (2 and 4 g/m^3) at atmospheric pressure.

HIGH FREQUENCY AND ARC PLASMA SOURCES FOR DEPOSITION ON DIELECTRIC SUBSTRATE

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Combination of high frequency and arc plasma sources were used to develop methods of applying metal contacts on the dielectric substrate. The influence of different high frequency modes on efficiency to reduce

the temperature during the deposition process and the impact on the residual droplet phase were studied based on the requirements nominated by the substrate to a temperature mode. These methods were used for applying different metal contacts to the growing surface of CVD diamond films Thus, the ionizing radiation detectors with ohmic contacts and low values of leakage currents were fabricated. Electro-physical characteristics of polycrystalline pCVD diamond film detectors were studied (current-voltage characteristics and pulse-height distributions of the detector signal under α irradiation). Analog sensitivity of diamond detectors under bremsstrahlung and electron irradiation was studied on linear accelerator LU-10 in NSC KIPT.

THE INCREASE IN THICKNESS UNIFORMITY OF FILMS OBTAINED BY MAGNETRON SPUTTERING WITH ROTATING SUBSTRATE

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The titanium thin films obtained by magnetron sputtering with the rotating substrate at different distances between the substrate and magnetron centers were studied with regard to the uniformity of the film thickness distribution. On the basis of the experimental data obtained, the model for the magnetron film deposition during substrate rotation was developed. The analysis of the simulation results shows that the model error is not greater than 10%.

STRUCTURAL AND MECHANICAL PROPERTIES OF OXIDE CERAMIC COATINGS FOR BIOMEDICAL APPLICATIONS

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Novel functional coatings are widelyapplied in different industrial areas as well as in bio-medicine. The aim of the study was the effect of structural properties of oxide coatings on their mechanical and wear resistance characteristics. Ceramic Al_2O_3 and Ta_2O_5 coatings were deposited in a high vacuum pumping system with a base pressure of about 10^{-2} Pa by ion source-assisted magnetron sputtering.The structures and surfaces parameters the investigated by means of TEM, SEM, XRD and XPS metod. Wear resistance testing was made by ball-disctribometry method. Nano hardness was measured by sclerometric method. Adhesion strength and friction coefficients were evaluated by scratch test method. Results show that mechanism of destruction andadhesive properties are different for ceramic oxide coatings. The development of advanced functional coatings with enhanced mechanical characteristics is very challenging for next bio-bearing, joints replacement and other biomedical applications.

AN APPLICATION FOR INACTIVATION OF *Escherichia coli, Bacillus subtilis, Streptococus* WITH ATMOSPHERIC PRESSURE MIXTURE PLASMA JET

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Plasma has being used for some applications like material processing, cutting metals and sterilization. Active species in the plasma provide advantages in the application areas. Plasma application has lots of advantages for

sterilization according to the classical methods. The classical sterilization methods require batch processing, radiation, high temperature and pressure but cold plasma, a type of plasma, does not need these conditions. There is no risk about chemical, heating or radiative dangers and it is cheaper than the low pressure system. In this study, our system is newly designed using a tungsten and aluminum electrodes with quartz tube that is like a pencil. The alternative current (AC) power supply is used. Differences between argon gas that is used to inactivation generally and argon/hydrogen mixture are experienced on the three type of bacteria (*Escherichia coli, Bacillus subtilis, Streptococus*). Hydrogen adding provides positive effective for sterilization as predicted.

INACTIVATION OF MICROORGANISM USING DIELECTRIC BARIER DISCHARGE PLASMA OF NEON

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A dielectric barrier discharge (DBD) plasma of neon (Ne) in atmospheric pressure at room temperature was obtained under a high frequency AC power supply. The microorganism inactivation by means of the DBD plasma jet were studied with eight kinds of typical microorganism, i.e. *Esherichia coli, Micrococcus luteus, Staphylococcus aureus, Salmonella typhimurium, Bacillus subtilis, Listeria monocytogenes, Candida albicans* and *Candida glabrata.* According to the Ne emission spectra of the plasma jet and the inactivation results of microorganism after the plasma treatment, it can be discussed that the reactive species in the Ne plasma had an important role in the inactivation of microorganism.

FTIR CHARACTERIZATION OF TREATED POLYCARBONATE

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Composition of the surface layer of polycarbonate (Lexan 8010), was studied by FTIR-spectroscopy. Polycarbonate was treated with a DC glow discharge in a flow of oxygen and air (pressure $50 - 300\,\mathrm{Pa}$ and the discharge current $20 - 110\,\mathrm{mA}$). The plasma treatment of polymer leads to increase in the absorption in the range of $3100 - 3500\,\mathrm{cm}^{-1}$ (stretching vibrations of O−H) and in $1650\,\mathrm{cm}^{-1}$ (vibrations of C=O in enol form −COH=CH−COOR), which indicates the formation of new oxygen-containing functional groups on the surface of the sample. The optical density measured at a wavenumber of $1650\,\mathrm{cm}^{-1}$ shows an increase with discharge current and gas pressure. At the same time the absorption at band maximum corresponding to vibrations of the C=O group in the ester ($1770\,\mathrm{cm}^{-1}$) is practically unchanged and remains at the level of the initial sample. Qualitative and quantitative changes in the composition of the polymer surface, obtained by plasma treatment in oxygen and air are close to each other.

This research has been supported by the RFBR, Project Number 16-32-00404.

A CONTROLLED REACTIVE HIGH-POWER IMPULSE MAGNETRON SPUTTERING ANALYZED BY OPTICAL EMISSION SPECTROSCOPY DURING DEPOSITION OF ZrO_2 FILMS

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A deposition of dielectric oxide films by a high-power impulse magnetron sputtering (HiPIMS) is a challenging task. At our department, a feedback pulsed reactive gas flow control (RGFC) system had been developed to utilize exclusive benefits of the HiPIMS in a high-rate reactive deposition of oxide films. The results of the optical

emission spectroscopy with a temporal resolution carried out during the deposition of densified stoichiometric ZrO_2 films using this system are presented. Oxygen was admitted into a vicinity of the magnetron target via two conduits with the inlets directed to the target or to the substrate. The actual O_2 flow through the conduits was adjusted by the RGFC system according to the monitored average discharge current in a period. The influence of the O_2 inlet configuration and of the power delivered to the discharge was examined for voltage pulses with the duration of $50\,\mu$s and $200\,\mu$s at the average target power density of up to $2.1\,\mathrm{kWcm^{-2}}$ in a pulse.

IMPACT LOW IONIZED PLASMA RADIATION OF AIR SPARK DISCHARGE ON AMINO ACIDS AND NITROGENOUS BASE

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Impact of low ionized plasma UVC radiation of air spark discharge on amino acids and nitrogenous bases was investigated. Primary active species produced under low ionized pulse plasma radiation are radicals $HO_2^{\cdot}$, $O^{\cdot}$ and N_2O. Secondary active species are HNO_2, HNO_3, $ONOO^-$ and ONOOH. If primary active species are at once interacted with substrate molecules, peroxynitrite and peroxynitrous acid don't produce. It was stated that amine and carboxylic acid functional groups of amino acids don't damage by pulsed plasma radiation, side-chain radical of amino acids can be oxidized or reduced. As result low molecular products: ketones and aldehides are appeared and accumulated. Breakup of bonds C−N and C−O take place in nitrogenous bases. In course of this process the ketones and aldehides also are produced. Carbonyl group (C=O) of ketones and aldehides don't destroyed under low ionized pulse plasma radiation, therefore ketones and aldehides are final products of destruction.

ATMOSPHERIC PRESSURE PLASMA GENERATION SYSTEM BASED ON PULSED VOLUME DISCHARGE FOR THE BIOLOGICAL DECONTAMINATION OF A SURFACE

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The research introduces a system for pulsed volume discharges ignition at atmospheric pressure within gaps reaching 125 mm. The corona discharge is used for the volume discharge initiation. A damping oscillations pulse generator is used as a high-voltage power supply. The pulse repetition rate reaches 1 kHz, while the rate of damping high-frequency harmonic oscillations can reach megahertz units. The volume discharge electric and spectral characteristics were analyzed. The study revealed that O_2^+ emission spectrum dominates in the UV region. The potential of using pulsed volume discharge for cleaning biological surfaces was demonstrated in the research. The survival rate for E.coli under the influence of 15 seconds long pulsed volume discharge has decreased by 30 times.

The reported study was supported by Russian Foundation for Basic Research (RFBR), research project No. 15-08-01707-a

TREATMENT OF INNER SURFACE OF LONG POLYMERIC TUBES USING A TRANSFERRED Ar PLASMA JET

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Recently, plasma sterilization of medical objects has become a hot topic with a certain interest of sterilizing small 3D objects with complex shapes, especially using cheaper approaches, i.e. cold atmospheric pressure plasmas operated in air or cheap gases (nitrogen or argon). This contribution is focused on basic study of Ar plasma treatment of inside surface of several commercial plastic tubes: silicone, polyurethane and polyvinyl. It will be demonstrated that the inner surface wettability of few meters long plastic tubes can be enhanced in one treatment by using a small plasma jet transferred through a thin long plastic tube, which is developed at FEG/UNESP. A comparison of plasma treatment efficiency together with a detailed description of the operation parameters (working gas, treatment time, input energy) will be presented and discussed.

This research has been supported by the FAPESP agency (project 2013/06732-3).

CHLOROBENZENE DECOMPOSITION BY THERMAL AC PLASMA OF STEAM, CARBON DIOXIDE AND METHANE

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A possibility of thermal plasma decomposition of organochlorine compounds by mixture of hydrogen and steam is proved. Thus hydrogen is produced by plasma reforming hydrocarbons (methane) using steam and carbon dioxide. Thermodynamic calculation of chlorobenzene decomposition by steam, carbon dioxide and methane at 500 – 2000 K is shown.

Results on obtaining the thermal plasma of methane, steam and carbon dioxide in a three phase AC plasma torch (Rutberg et al: J. Phys. D: Appl. Phys. 48 (2015) 245204, Rutberg et al: Applied Energy 148 (2015) 159–168, Rutberg et al, High Temperature. 51 (2013) 5) at a flowrate H_2O^- 2.9 g/s and CO_{2-} 2.9 g/s, CH_{4-} 0.3 g/s were estimated. Experimental data on the de-composition of chlorobenzene at a flow rate of chlorobenzene vapor from 0.5 to 4 g/s were obtained.

MAGNETRON SPUTTERED Hf–B–Si–C–N FILMS WITH ULTRAHIGH THERMAL STABILITY IN AIR

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The present work focuses on the effect of nitrogen addition into Hf−B−Si−C films in order to significantly improve the oxidation resistance of these films. Hf−B−Si−C−N films were deposited onto Si(100) and SiC substrates using pulsed magnetron co-sputtering of a single B_4C−Hf−Si target (at a fixed 15% Hf fraction and a 20% Si fraction in the target erosion area) in an Ar+N_2 gas mixture at the N_2 fraction ranging from 0% to 50%. A planar unbalanced magnetron was driven by a pulsed DC power supply operating at a repetition frequency of 10 kHz with an average target podwer of 500 W in a period and a fixed 85% or 50% duty cycle. Substrates were held at a floating potential and a temperature of 450 °C. The $Hf_7B_{25}Si_{21}C_5N_{40}$ film with 2 at.% of Ar possessing hardness of 20 GPa and electrical resistivity of $2 \times 10^{-1}\ \Omega$m exhibited very high oxidation resistance even above 1500 °C.

DEGRADATION OF VERAPAMIL IN WATER USING ADVANCED OXIDATION PROCESSES

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The presence of pharmaceutical compounds has been detected in the aquatic environment. Although the amount of these substances in the surface water is low, its continuous input may constitute in the long-term a potential risk for aquatic and terrestrial organisms. Therefore, over the past few years they are considered as emerging pollutants in water bodies and their removal may be necessary for water use or reuse applications. This study investigated the influence of spark discharge plasma and ozonation on the degradation of verapamil in water. In the case of spark discharge, 87% of verapamil has been degraded within 40 min. and the obtained energy yield is 5×10^{-2} g/kWh for an initial concentration of 5×10^{-5} M. With ozonation, 100% verapamil has been removed within 1.5 min. with an energy yield of 9.4 g/kWh for an initial concentration of 5×10^{-5} M. Our ozonizer is much more efficient than the pulsed spark discharge in the degradation of verapamil in water.

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LIQUID ASSISTED ELECTRICAL DISCHARGE SYNTHESIS AND MODIFICATION OF SILICON AND CARBON QUANTUM DOTS

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The capabilities of the liquid assisted electrical discharge technique for synthesis of silicon and carbon nanocrystalls, promising for biomedical and photovoltaic applications are discussed. The nano-sized Si particles with a diameter of about 5 nm were synthesized, and a mechanism of their formation was suggested. The sizes of the carbon NPs were distributed in the range of $2-5$ nm with an average value of 3 nm. The carbon NPs have strong luminescence in the visible region. The excitation-dependent PL behavior of C-dots can be attributed to the differences in sizes of NPs and/or different emissive sites on NPs surfaces. The atmospheric-pressure dc microplasma was used for surface modification of as-prepared NPs directly in solution. The plasma treatment induces non-equilibrium liquid chemistry that passivates the surface of nanocrystals and results in increasing their photoluminescence. The surface chemistry induced by the plasma treatment is analyzed.

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BACTERIA INACTIVATION BY SYNERGISTIC EFFECTS OF NON-THERMAL PLASMA AND OREGANO ESSENTIAL OIL

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Bactericidal effects of essential oil solution sprayed by non-thermal plasma were investigated. 6 μl of Oregano essential oil dispersed in distilled water with 5% Tween 80 was electro-sprayed through DC-driven positive spark discharge in air onto the bacterial inoculum on agar surface. Bactericidal parameters of this electro-spraying were compared with essential oil mechanical spraying. Up to 8 orders of inactivation was reached after 4 minutes of electro-spraying (with flow rate 50 Âţl/min) for bacteria (*E. coli, S. aureus, D. radiodurans* and *S. cerevisiae*).

This research has been supported by the Student Grant Agency CTU under grant No. SGS16/223/OHK3/3T/13.

THICKNESS DEPENDENT WETTING PROPERTIES OF THIN FILMS OF CERAMICS BASED ON LOW-ELECTRONEGATIVITY METALS

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We have previously shown (Zenkin, Kos, Musil, J. Am. Ceram. Soc. 97 (2014) 2713–2717) that compounds of low-electronegativity metals form intrinsically hydrophobic hard ceramics. Dominant component of the surface free energy of these ceramics is the electrostaticLifshitz-van der Waals component, strongly suggesting a thickness dependence of the wetting properties. We used the reactive high power impulse magnetron sputtering with a pulsed reactive gas flow control as a technique capable of producing dense films with smooth surfaces and well controlled thickness. We have found that for HfO_2 films a thickness dependence of the water droplet contact angle ranging from 120° for the thickness of 50 nm to 100° for the thickness of 2300 nm. The XRD and FTIR showed only minor differences among the films. We propose two explanations for the observed thickness dependence: influence of the sub-dominant texture and/or non-monotonic size dependence of the crystal grain surface energy.

HARD ANTIBACTERIAL Zr–Cu–N COATINGS WITH RESISTANCE TO CRACKING

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The present paper reports on the preparation of hard antibacterial Zr−Cu−N coatings with resistance to cracking. The coatings were deposited by reactive pulsed dc dual magnetron sputtering of two identical circular Zr/Cu targets in $Ar+N_2$ gas mixtures. The effect of the addition of Cu (from ~ 0.5 at. % to ~ 16 at. %) on the structure, antibacterial and mechanical properties, and resistance to cracking was investigated in detail. It was found that the Zr−Cu−N coatings prepared at optimized deposition conditions exhibit a high hardness ranging from ~ 21 GPa to ~ 31 GPa, high ratio $H/E^* > 0.1$, high elastic recovery $> 60\%$ and are in compressive macrostress. These conditions simultaneously result in an enhanced resistance to cracking in bending and under indentation. Moreover, the coatings with the Cu content > 11 at. % exhibit 100% efficiency of killing *E. coli* bacteria on their surface.

PLASMA THRUSTERS: PRINCIPLES, APPLICATIONS, DIAGNOSTICS

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The presentation is divided into two parts. The first part presents a short review of electric propulsion technologies for satellites and spacecrafts. Plasma thrusters are classically grouped into three categories according to the thrust generation process: electrothermal, electrostatic and electromagnetic devices. The three groups are presented via a discussion of the examples of long-standing technologies like arcjet, magnetoplasmadynamic and pulsed plasma thrusters, ion engines as well as Hall-effect thrusters.

The second part is concentrated on the electric probe diagnostic of two types of Hall-effect thrusters. Applied is the Langmuir and emission probe techniques in time-averaged and time-resolved modes in the far-field plasma plume of the thrusters. Finally, the time-resolved electron energy probability function measurements are presented from which an interpretation of the breathing oscillations as a wave propagating downstream with approximately ion sound velocity is inferred.

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SYNTHESIS OF ALLOYED NANOPARTICLES BY SPARK DISCHARGES IN LIQUIDS: BETWEEN MYTH AND REALITY

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High-rate and low-cost synthesis of nanoparticles can be achieved by plasmas in liquids. When spark discharges are ignited in a dielectric liquid, a strong heating of the electrode material occurs, producing a metallic vapor from which nanoparticles grow by condensation. This process can be conveniently used to synthesize core-shell nanoparticles. Indeed, by processing between two metallic electrodes formerly synthesized nanoparticles, it is possible to coat them and produce core-shell nanostructures.

By contrast, producing alloy nanoparticles by discharges in liquids is much more complex. To understand the reasons of this behavior, several experiments were done to synthesize CuZn and CuAg alloys by discharges in liquid nitrogen.

We will show that the main difficulty associated with the synthesis of nanoparticles is due to the differential melting of elements. Once evaporated, metallic vapors never recombine in the plasma but produce separated nanoparticles of each type of metal.

A VALIDATED AND CERTIFIED DBD-SOURCE: FROM BASIC MEASUREMENTS TO WOUND HEALING

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Dielectric barrier plasma sources (DBD) are well-known in surface treatment since centuries. In recent years, wound healing became a new topic, since DBD plasmas are inherently cold, deliver feasible electron densities and suppress VUV radiation due to their operation in air. On the other hand, the mechanisms of air plasma on bacteria, on skin cells and on dry and humid proteins is not fully understood. It turned out that the treatment of dry and humid biological material, e.g. proteins, are completely different in its efficancy. A careful study of treated samples with CD-spectroscopy, Raman spectroscopy, FTIR and mass spectrometry shows a clear correlation between oxygen fluences measured in the DBD and modification of proteins at distinct parts in the primary and secondary structure of proteins. The talk presents the quantitative diagnostic of an accredited DBD source, absolute measured fluxes of ROS and their influence on biological material (proteins).

This research has been supported by the Deutsche Forschungsgemeinschaft (DFG), PlasmaDecon, Placid (Plasma2Cell).

SYNTHESIS OF NOVEL FUNCTIONAL FILMS BY CONTROL OF ELECTRON TEMPERATURE AND DENSITY WITH RF TO UHF HYBRID PLASMA

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Electrons, ions, radical species and neutrals play a critical role in nucleation and growth and corresponding film microstructure as well as plasma-induced surface chemistry, especially in the plasma-assisted deposition. These aspects are closely associated with deposition energy which is controlled by these species. In this sense, the necessity of dedicated experimental studies, diagnostics and modeling of process plasmas to quantify the effect of the unique chemistry and structure of the growing film by radical and plasma control is realized. This will account for the identification, determination and quantification of the surface activity of the species in the plasma. This presentation addresses on the novel design and control of plasma processes for synthesis of Si based films from nano crystalline to Si quantum dot with various plasmas. Different low-temperature processes using RF, UHF, and RF/UHF hybrid plasmas are investigated using numerous diagnostics and film analysis tools.

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RF PLASMA POLYMERISATION FOR FABRICATION OF CARBON MATERIALS

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RF Plasma polymerisation (plasma assisted chemical vapour deposition PECVD) has been widely used to fabricate carbon materials such as graphene or diamond like carbon (DLC) from different precursors. One of the main advantages of PECVD is that the fabrication temperature can be substantially decreased and hence many unconventional substrate materials can be used and hence device integration is feasible. Also RF generated plasma allows to use many unconventional precursors as the source for carbon. This presentation will also scrutinise the use of many natural resources as the source of carbon for graphene or DLC fabrication. Number of deposition parameters such as input RF power, pressure, monomer flow etc can be varied to tailor the material properties and hence enable the material fabrication suitable for various applications.

LOW PRESSURE PLASMA FOR THIRD GENERATION SOLAR CELLS BASED ON NANOCRYSTALS WITH QUANTUM CONFINEMENT EFFECTS

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Doping of quantum confined nanocrystals offers unique opportunities to control the bandgap and the Fermi energy level. In this contribution, boron-doped and phosphorus-doped quantum confined silicon nanocrystals (Si-ncs) are surface-engineered in colloidal solution by an atmospheric pressure radio frequency microplasma. We demonstrate that surface chemistries induced on the Si-ncs strongly depend on the type of dopants and implications for third generation solar cells are discussed. In particular surfactant free microplasma surface-engineered Si-ncs can be integrated into the device architecture to be optically active and provide a means of effective down-conversion of blue photons into red photons leading to 24% enhancement of the photocurrent under concentrated sunlight. We also demonstrate that the down-conversion effect under 1-sun is enhanced in the case of hybrid solar cells where microplasma engineered Si-ncs are also beneficial in the active absorption layer of the solar cells.