1st PLASMA FOR NANOTECHNOLOGY AND BIOAPPLICATIONS WORKSHOP

Scientific Program & Book of Abstracts

Telč, Czech Republic, December 8–10, 2019

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1st Plasma for Nanotechnology and Bioapplications Workshop

SCIENTIFIC PROGRAM
&
BOOK OF ABSTRACTS

MUNI

Telč, Czech Republic, December 8–10, 2019

1st Plasma for Nanotechnology and Bioapplications Workshop
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Edited by

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PREFACE

Dear colleagues,

You are holding in your hands the *Scientific Program & Book of Abstracts* for *1st Plasma for Nanotechnology and Bioapplications workshop*. The impulse to organize this event was the effort to enable the researchers and doctoral students to share and exchange their knowledge, experiences and results from the basic and applied research of Plasma Physics, Physics of Electrical Discharges and Plasma Chemistry. The workshop is attended by the researcher teams from CEPLANT, Department of Physical Electronics, Faculty of Science, Masaryk University in Brno, and Department of Experimental Physics, Faculty of Mathematics, Physics and Informatics, Comenius University in Bratislava, both very active in the above mentioned scientific fields. Within the workshop the contributions from the following five topics: *Surface Modification; Flexible Electronics; Plasma Discharges and Sources; Bioapplications;* and *New Materials & New Challenges* will be presented in the form of oral presentations.

I am convinced that the relaxed and friendly atmosphere of the workshop that I would wish, as well as the attractive venue of the event in the University Centre of Masaryk University located in the historical centre of Telč, guarantee a pleasant and supportive scientific experience and ideas for the participants.

Dušan Kováčik

SCIENTIFIC PROGRAM

Sunday, 8th December 2019

17:00–18:00 Arrival & Check-in and accommodation

18:30–23:00 Welcome party

Monday, 9th December 2019

7:00–8:30 Breakfast

TOPIC 1: SURFACE MODIFICATION Chairman: Zlata Kelar Tučeková

8:45–8:50	Opening words
8:50–9:10	**R. Krumpolec:** *Reducing atmospheric plasma for plasma modification of materials*
9:10–9:30	**D. Kováčik:** *Optimization of polyamide foils adhesion properties used as casings for meat products by atmospheric pressure plasma treatment*
9:30–9:50	**S. Sihelník:** *Fast large-area precleaning and activation of float soda-lime glass using non-thermal plasma at atmospheric pressure*
9:50–10:10	**O. Galmiz:** *Effect of DCSBD plasma treatment on surface properties of thermally modified wood*

10:10–10:40 Coffee break

TOPIC 1: SURFACE MODIFICATION Chairman: Anna Zahoranová

10:40–11:00	**D. Kováčik:** *Plasma polymerization of acrylic acid on polypropylene nonwovens and foils initiated by diaphragm discharge*
11:00–11:20	**P. Šramková:** *Hydrophilic poly(2-oxazoline) coatings prepared by non-equilibrium "cold" atmospheric pressure plasma*
11:20–11:40	**G. Zrubcová:** *Preparation of ceramic nanofibers by electrospinning process and plasma treatment*
11:40–12:00	**J. Surovčík:** *Preparation of Al_2O_3 nanofibers by thermal calcination with low temperature plasma pre-treatment*

12:00–13:00 Lunch

13:00–16:00 Free time & Informal discussion

TOPIC 2: FLEXIBLE ELECTRONICS Chairman: Richard Krumpolec

16:00–16:20	**T. Homola:** *Nano- and bio-applications of plasma to the rapid manufacture of flexible and printed electronics, part I*
16:20–16:40	**T. Homola:** *Nano- and bio-applications of plasma to the rapid manufacture of flexible and printed electronics, part II*
16:40-17:00	**M. Shekargoftar:** *Atmospheric pressure plasma to tune perovskite surface properties for enhancing the performance of solar cells*

17:00–17:30 Coffee break

TOPIC 3: PLASMA DISCHARGES and SOURCES Chairman: Dušan Kováčik

17:30–17:50	**J. Kelar:** *Flexible ceramic substrates for use as dielectric barrier layer*
17:50–18:10	**M. Zemánek:** *HV generators for DCSBD discharges and their properties*
18:10–18:30	**M. Pazderka:** *RC-probe and peaks suppression in DBD voltage measurements*
18:30–18:50	**S. Omasta:** *Time delay of low-energy electrical breakdowns in water and plasma activation of water by different plasma sources*

19:00–20:00 Dinner

Tuesday, 10th December 2019

7:00–8:30 Breakfast

TOPIC 4: BIOAPPLICATIONS Chairman: Vlasta Štěpánová

8:30–8:50	**A. Zahoranová:** *Possibilities of DCSBD plasma application in agriculture: germination improvement and surface disinfection*
8:50–9:10	**V. Medvecká:** *The effect of low-temperature plasma on decontamination and qualitative characteristics of sprouts, nuts and spices*
9:10–9:30	**S. Siadati:** *Influence of cold atmospheric plasma jet on four different yeast species*
9:30–9:50	**J. Tomeková:** *Optical diagnostics of DCSBD plasma for bioapplications*

9:50–10:20 Coffee break

TOPIC 4: BIOAPPLICATIONS Chairman: Veronika Medvecká

10:20–10:40	**V. Štěpánová:** *Effect of plasma treatment on seeds before coating with agrochemicals and its influence on seeds dustiness*
10:40–11:00	**Z. Kelar Tučeková:** *Multi-hollow surface dielectric barrier discharge for decontamination*

TOPIC 5: NEW MATERIALS & NEW CHALLENGES Chairman: Dušan Kováčik

11:00–11:20	**R. Krumpolec:** *Deposition of copper halide films for optoelectronic applications*
11:20–12:20	Open discussion related to current contract research, new infrastructure and equipment, planned projects
12:20–12:30	Closing words

12:30–13:30 Lunch & Departure

LIST OF ATTENDEES

Masaryk University, Faculty of Science,
Department of Physical Electronics

doc. Mgr. KOVÁČIK Dušan, PhD.

prof. RNDr. ČERNÁK Mirko, CSc.

doc. RNDr. HOMOLA Tomáš, PhD.

Ing. ZEMÁNEK Miroslav, Ph.D.

RNDr. KRUMPOLEC Richard, PhD.

RNDr. KELAR TUČEKOVÁ Zlata, PhD.

Mgr. ŠTĚPÁNOVÁ Vlasta, Ph.D.

Mgr. ŠRÁMKOVÁ Petra, PhD.

Mgr. PAVLIŇÁK David, Ph.D.

Mgr. GALMIZ Oleksandr, Ph.D.

Mgr. KELAR Jakub

Mgr. SHEKARGOFTAR Masoud

Mgr. SIHELNÍK Slavomír

Mgr. VIDA Július

Mgr. ZRUBCOVÁ Galina

Mgr. PAZDERKA Michal

MSc. FENG Jianyu

Comenius University, Faculty of Mathematics,
Physics and Informatics,
Department of Experimental Physics

doc. RNDr. ZAHORANOVÁ Anna, PhD.

RNDr. MEDVECKÁ Veronika, PhD.

SIADATI Seyedehneda, PhD.

Mgr. TOMEKOVÁ Juliána

Mgr. OMASTA Samuel

Mgr. SUROVČÍK Juraj

ABSTRACTS

TOPIC 1

SURFACE MODIFICATION

REDUCING ATMOSPHERIC PLASMA FOR PLASMA MODIFICATION OF MATERIALS

Richard KRUMPOLEC, Zlata KELAR TUČEKOVÁ,
Jakub KELAR, Zdeňka DOUBKOVÁ, Miroslav ZEMÁNEK

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Abstract

Atmospheric pressure plasma generated by diffuse coplanar surface barrier discharge (DCSBD) is routinely used in ambient air and standard gases such as nitrogen and oxygen. Using these gases, typically oxidation reactions are carried out, and generated plasma is used for surface cleaning, activation and other surface modifications of various materials. The DCSBD plasma can be, however, generated also in pure reducing gases and its mixtures such as hydrogen, argon, methane, and a forming gas to perform reducing reactions for reduction and etching of materials. During the last two years under the TAČR Zéta project, we have studied different applications of reducing DCSBD plasmas, particularly surface etching of thin polymer films and plasma nanostructuring of polymers, plasma reduction of thin TiO_2 films and powders, as well as plasma modification of polymers for adhesion improvement [1–3].

Based on the request for large-area plasma modification of flexible substrates, a new reactor capable of roll-to-roll (R2R) plasma processing of flexible materials in any working atmosphere was also developed. The device, equipped with two DCSBD plasma units, can treat flexible foils, paper, etc. up to the width of 200 mm at a processing speed of 0.25–32 cm.s^{-1} (plasma treatment time 0.25–30 s / single plasma unit) in all standard working gas. A new localized gas dosing unit installed in the processing chamber significantly decreases working gas consumption and thus contributes to increasing the safety of the device.

The advantages of the application of hydrogen DCSBD plasma is discussed on examples of two experiments in more details.

Pure hydrogen DCSBD plasma was found strongly selective in the surface etching of metal-polymer composite mesh substrates and thus moderate etching process influenced mainly polymeric structures rather than metallic ones. In contrast, the etching in ambient air, pure N_2, and N_2/H_2 mixtures, resulting in a strong degradation both the polymer and metal parts of the substrate and therefore those plasmas are not suitable for that particular application.

The reason for the application of pure hydrogen plasma instead of simple ambient air plasma is discussed on the results of plasma modification of polytetrafluoroethylene (PTFE) for improvement of its surface adhesion properties. X-ray photoelectron spectroscopy was used for detailed study if plasma-chemical changes on the PTFE surface after plasma modification in ambient air and pure H_2 plasma. As observed, plasma modification of the PTFE surface by reducing H_2 plasma led to completely different surface chemistry. Such plasma-treated surface was then studied for improvement of painting adhesion on PTFE and for adhesion improvement of glued joints of PTFE-like shell of solar tubes into plastic housing. As revealed PTFE treated by H_2 plasma exhibited the best adhesion results.

This work was supported from the project LO1411 (NPU I), funded by the Ministry of Education, Youth and Sports of the Czech Republic and from the project TJ01000327, funded by Technology Agency of the Czech Republic.

Keywords: atmospheric plasma, reducing plasma, hydrogen, surface treatment, reduction, etching

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OPTIMIZATION OF POLYAMIDE FOILS ADHESION PROPERTIES USED AS CASINGS FOR MEAT PRODUCTS BY ATMOSPHERIC PRESSURE PLASMA TREATMENT

Dušan KOVÁČIK, Vlasta ŠTĚPÁNOVÁ, Slavomír SIHELNÍK, Petra ŠRÁMKOVÁ, Monika STUPAVSKÁ, Jana JURMANOVÁ

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Abstract

Polyamide (PA) foils provide a unique combination of properties like mechanical strength, thermo-formability, high transparency, and excellent barrier characteristics which predetermine their application in the food industry as flexible packaging material, e.g. in the meat processing industry as artificial casings for sausages and ham. Similarly to other polymeric materials, PA is characterized by low surface energy, bad wettability and poor adhesion properties. Therefore, for most of the application, the surface of PA foils must be treated. Plasma represents an excellent, environmentally friendly and efficient tool for surface treatment of many materials.

The main objective of this study was to optimize the plasma treatment conditions to achieve the desired adhesion properties of the polyamide foils used as the casings for a meat product. Therefore, it has been necessary to carry out the treatment mainly of the inner side of PA foil, which is in direct contact with the meat mixture. For the study we utilize the diffuse coplanar surface barrier discharge (DCSBD) as a source of "cold" atmospheric pressure plasma housed in a roll-to-roll reactor for high-speed treatment of flexible material in a continuous regime. To demonstrate the efficiency of DCSBD plasma treatment PA foils were also treated by industrial corona roll-to-roll reactor from Ahlbrandt System GmbH. Optimization included assessment of the optimal exposure time, a distance of foils from ceramics of the DCSBD electrode system,

discharge input power and working gas. Accordingly, we monitored the influence of two different discharge input powers (400, 600 W), selected plasma exposure times (0.25, 0.5, 1 and 2 s), three distances of sample from the electrode (0.3, 0.4, 0.5 mm) and two working gases (ambient air, nitrogen) on wettability, the ageing of plasma treatment, adhesion properties, morphology and chemical composition of the PA foils.

A significant decrease in water contact angle (WCA) from an initial value of 65.4° ± 1.3° was achieved already after 0.25 s for both used DCSBD input powers. The ageing process was more pronounced for the foils treated at 400 W in comparison to 600 W; however, WCA values of all foils were still far from the initial value even after 30 days. The distance of the treated sample from the electrode at 0.3 mm was determined as the most effective concerning the rate of hydrophobic recovery. It was also proved that the treatment by DCSBD plasma is much more effective and durable compared to the industrial corona treatment. Moreover, we investigated the adhesion properties of PA foil on its outer (exposed) and inner (non-exposed) side after plasma treatment. The results from the tape peel test showed the significant adhesion enhancement of DCSBD plasma treated foils. In the collaboration with the external industrial partner we carried out also the standard tests of adhesion properties of PA inner side to two different meat mixture. The results of these tests confirmed the significant effect of DCSBD plasma treatment on the adhesion enhancement of the inner side of treated PA foil. Scanning electron microscopy (SEM) revealed that the DCSBD plasma treatment is gentle to the surface of PA foils and does not lead to any changes in morphology. The results of X-ray photoelectron spectroscopy (XPS) gave us information about the chemical composition changes after plasma treatment of PA foils. We can suppose that the hydrophilic character of plasma treated PA foils is caused mainly by the incorporation of polar functional groups containing oxygen to the surface.

This research has been supported by the project MUNI/31/63965/2018 funded by Masaryk University.

Keywords: plasma treatment, polyamide foil, DCSBD, industrial corona, adhesion

FAST LARGE-AREA PRECLEANING AND ACTIVATION OF FLOAT SODA-LIME GLASS USING NON-THERMAL PLASMA AT ATMOSPHERIC PRESSURE

Slavomír SIHELNÍK[1], Jakub KELAR[1], Miroslav ZEMÁNEK[2], Oliver BEIER[3], Zlata KELAR TUČEKOVÁ[1], Richard KRUMPOLEC[1], Monika STUPAVSKÁ[1], Jozef RÁHEĽ[2], Jost WITTWER[4], Bernd GRÜNLER[3], Andreas PFUCH[3], Dušan KOVÁČIK[2], Mirko ČERNÁK[2]

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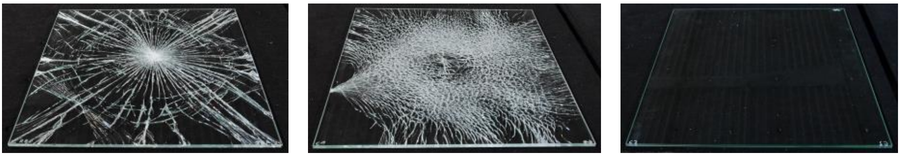
Abstract

Soda-lime glass (SLG) is the most used substrate material in the manufacturing of coated, layered and bonded glass products tailored to specific applications. Adhesion as essential processing property is mainly dependent on cleanness, roughness and chemical activity of the substrate's surface. Application of non-thermal plasma treatment was studied as a gentle environmentally friendly dry supplement or replacement of conventional wet mechanical cleaning methods of float SLG. Targeting the main industrial requirements of speed, scale and costs, various plasma sources working with air at atmospheric pressure were examined: plasma beam, gliding arc, diffuse coplanar (DCSBD) [1] and multihollow (MSDBD) [2] surface dielectric barrier discharges. The experiments intended for contactless achieving of non-invasive, uniform and stable effect were evaluated by measurements of water contact angle (WCA), analyses with X-ray photoelectron spectroscopy (XPS), atomic force microscopy (AFM) and laser scanning, observation of stearic acid layer decomposition by Fourier-transform infrared (FTIR) spectroscopy, and finally corrosive and mechanical tests of powder coating adhesion. Based on the results that showed high

efficiency at optimal conditions with the use of the DCSBD plasma, subsequent experiments were performed with its contactless and in-line implementations directly in a factory environment. Industrial mechanical tests of screen-printed, digital-printed and layered products made with additional plasma pretreatment resulted in the best improvement in laminated safety glass (LSG) manufacturing. The automatic ball drop test demonstrated an impressive enhancement of LSG crash resistance shown in *Fig. 1*. A remarkable LSG toughening was noted in the bending test that evaluated breaking force progress at 46 % on average for the use of DCSBD plasma-treated glass.



No plasma treatment | Plasma-treated glass | Plasma-treated glass and PVB film

Fig. 1: Ball drop test of safety laminated glass made with the implementation of DCSBD plasma.

This research has been supported by the projects "Alternative methods for processing glass using atmospheric pressure plasma technology", CZ.01.1.02/0.0/0.0/16_053/0007132 funded by the European Regional Development Fund and by the German BMWi under grant No. ZF4028609AG6.

Keywords: float soda-lime glass, plasma beam, gliding arc, DCSBD, multihollow SDBD, contactless leading, laminated safety glass

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EFFECT OF DCSBD PLASMA TREATMENT ON SURFACE PROPERTIES OF THERMALLY MODIFIED WOOD

Oleksandr GALMIZ[1], Rasmus TALVISTE[2], Zlata KELAR TUČEKOVÁ[1], Monika STUPAVSKÁ[1], Radan PANÁČEK[3], Jozef RÁHEL'[1], Dušan KOVÁČIK[1]

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Abstract

This study was focused on the treatment of thermally modified wood of different species with the diffuse coplanar surface barrier discharge (DCSBD). Surfaces were characterized before and after the DCSBD plasma exposure with different treatment time by scanning electron microscopy (SEM), X-ray photoelectron spectroscopy (XPS), confocal microscopy and contact angle measurements.

Surface free energy of 63–64 mJ/m^2 was measured for all thermally modified wood species already after 5 and 10 s of plasma treatment. XPS measurements showed a pronounced increase of O/C ratio after plasma treatment. Depending on the wood species the reference value for O/C ratio was 0.2–0.3 and it increased to 0.5–0.7 and 0.7–0.8 after 10 and 60 s of plasma treatment, respectively. SEM imaging revealed that on the micrometer scale the surface morphology did not change after the plasma treatment. However, nanoscale structuring was observed at higher magnification after longer plasma treatment of 60 s [1].

In order to study the nano-structuring effect, the diffuse coplanar surface barrier discharge was applied for treatment of aspen (*Populus tremuloides*) and thermally modified aspen. The effect of treatment time and distance between the planar

electrode and the sample on the formation of nanostructures was observed. The formed structures were studied with confocal and scanning electron microscopy and attenuated total reflectance Fourier transform infrared spectroscopy. The size of the structures was in the range of 20-100 nm but no effect on the mean height of the surface was detected i.e. the microscale surface roughness was unchanged. Increased treatment time influences surface structuring as a result of plasma etching. The optimal gap was found to be around 0.2-0.3 mm for this configuration. Infrared spectra indicated that plasma treated surfaces exhibited a higher content of aromatic structures present in lignin [2].

Recently, it was observed that the effect of wood plasma treatment mediated by diffuse coplanar surface barrier discharge (DCSBD) depends strongly on the distance between the treated surface and the DCSBD electrode [3]. Plasma treatment at distances up to 0.4 mm renders a more hydrophilic wood surface. On the other hand, at distances above 0.6 mm, the water contact angle increases, i.e. the surface becomes more hydrophobic. To unveil the possible mechanisms involved, this study was focused on plasma treatment of European beech (*Fagus sylvatica*) surfaces with varying distance (0.15, 0.45 and 1 mm) from the electrode. In addition to the treatment in the air also O_2, CO, N_2 and Ar atmospheres were employed. Based on additional tests with cellulose paper and previous studies, the reason for increased hydrophobicity was suggested to be the degradation of hemicellulose. Treatment in O_2, CO_2, and Ar at 1 mm increased the polar part, which was explained by increased O/C ratio on the surface. It was suggested that in O_2 and CO_2 this was caused by a higher concentration of ozone compared to air plasma while in Ar the cause was most likely a post-treatment oxidation.

Keywords: plasma, thermally modified wood, nanostructures, surface free energy

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PLASMA POLYMERIZATION OF ACRYLIC ACID ON POLYPROPYLENE NONWOVENS AND FOILS INITIATED BY DIAPHRAGM DISCHARGE

Dušan KOVÁČIK[1,2], Patrícia MULTÁŇOVÁ[1], Seyedehneda SIADATI[1], Oleksandr GALMIZ[1,2], Petra ŠRÁMKOVÁ[2], Pavol ĎURINA[1], Michal STANO[1], Monika STUPAVSKÁ[2], Anna ZAHORANOVÁ[1]

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Abstract

In our contribution, we provide the straightforward method for plasma-assisted polymerization of acrylic acid (AAc) on fibres of polypropylene nonwoven textile (PPNT) and biaxially oriented polypropylene (BOPP) foil by using the so-called diaphragm discharge generated in AAc water solution. Acrylic acid is a widely used precursor for modification of different materials with the aim to develop surface with specific properties or promote further immobilization of desired structures. Moreover, plasma-assisted polymerization of AAc provides an easier alternative to challenging chemical processes, because electrical discharge generated in a water solution of AAc initiates polymerization reaction without the use of additional chemicals. Application areas of such AAc modified surfaces include, e.g. battery separators, interfacial bonding layers in structural adhesive joints, as well as bio-medical interfaces. Concerning the potential medical applications, AAc represents an important precursor for the formation of functionalized layers with exclusively attached carboxylic acid groups suitable for further biomolecules immobilization processes. Our main objective was to adjust the appropriate conditions of the plasma polymerization procedure to achieve the continual process, which could provide the homogeneous distribution of AAc layer on fibres of thin PPNT and additionally on BOPP foil. Therefore, we selected four different concentration of AAc water solution 5, 10, 20 and 30°% that corresponded to the conductivity of solution 1.9, 2.4, 2.1 and 1.7 mS/cm, respectively and two plasma exposure times (3.5 and 5 s) to control the resulting characteristics of

deposited PPNT and BOPP foil. For generation of diaphragm discharge the high pulse voltage (~25 kV) with a frequency of 100 Hz was applied. The wettability of treated nonwovens was examined by strike-through time measurement and surface energy estimation using Critical wetting surface tension (CWST) method immediately after treatment as well as 2, 4 and 8 weeks later to study the permanency of hydrophilic treatment. In the case of BOPP foils for determination of wettability changes, the water contact angle measurement was carried out. For PPNT it was confirmed the stable hydrophilic character of polyacrylic acid (pAAc) surface of PPNT fibres. X-ray photoelectron spectroscopy (XPS) and Fourier-transform infrared spectroscopy (FTIR) were used to monitor the chemical composition of AAc binding to PPNT and confirmed the presence of deposited pAAc layer. The formation and thickness of the pAAc layer on the surface of PPNT fibres was also proved by Scanning electron microscopy (SEM), as shown in Fig. 1. The presence of pAAc on the fibres and the higher surface energy of PPNT resulted in the higher adhesion properties what was confirmed by the results of the tape peel test measurement. On the other side, the treatment of BOPP foil in the AAc water solution by diaphragm discharge resulted in inhomogeneous treatment and partial damage of foil. Therefore, there is a need to optimize the conductivity of the solution, which influences the number and distribution of microdischarges in diaphragm discharge and also its pH in connection with the elimination of chemical interaction with the film.

The presented work was supported by the Slovak Grant Agency for Science VEGA No. 1/0930/17.

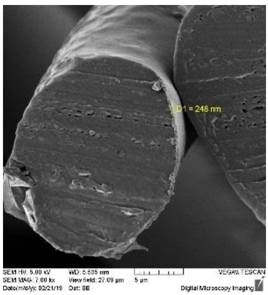

Fig. 1: SEM image of pAAc layer on the surface of PPNT fibre prepared by plasma polymerization.

Keywords: acrylic acid, plasma polymerization, polypropylene nonwovens, polypropylene foil, diaphragm discharge

HYDROPHILIC POLY(2-OXAZOLINE) COATINGS PREPARED BY NON-EQUILIBRIUM "COLD" ATMOSPHERIC PRESSURE PLASMA

Petra ŠRÁMKOVÁ[1], Anna ZAHORANOVÁ[2], Jakub KELAR[1],
Zlata KELAR TUČEKOVÁ[1], Monika STUPAVSKÁ[1], Jana JURMANOVÁ[1],
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Abstract

Due to biological inertness and excellent stability, polytetrafluoroethylene (PTFE) is extensively used for the manufacturing of vascular grafts and various implants. However, its highly hydrophobic nature is disadvantageous for specific biomedical applications requiring the control of the proteins or cell adhesion [1]. Hydrophobicity can be decreased by surface modification using the various biocompatible polymers.

In our contribution, we propose the new method for PTFE surface coating by synthetic hydrophilic polymers, so-called poly(2-oxazolines) (POx). Immobilization of the POx layer is performed employing non-equilibrium "cold" atmospheric pressure plasma generated by the diffuse coplanar surface barrier discharge (DCSBD) [2]. Our main objective is to achieve the stable and biologically active cross-linked POx layer immobilized on the PTFE surface.

The experimental procedure for the preparation of POx-based coating is depicted in Fig. 1. The POx layer was deposited on the plasma-activated PTFE surface and subsequently post-treated by DCSBD plasma either in an atmosphere of ambient air or argon to compare the effect of working gas on chemical changes and coating stability.

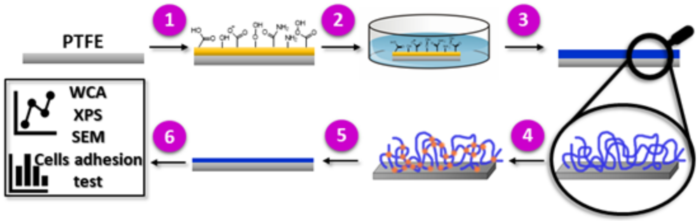

Fig. 1: Experimental procedure for preparation of POx-based coating: (1.) plasma activation of PTFE surface, (2.) dip-coating of POx layer, (3.) drying, (4.) plasma post-treatment of POx layer (air and argon used as working gases), (5.) washing in distilled water, (6.) characterization.

Scanning electron microscopy, as well as X-ray photoelectron spectroscopy, confirmed the presence of a thin POx layer on the PTFE surface. We observed the decreasing of water contact angle from an initial value of 105.6° ± 3.9° to values within the range of 60-63° that remained stable for one month. In comparison to pristine PTFE, which does not promote the cell adhesion, the presence of the POx layer on the surface increased cell adhesion, which is beneficial, for example, in tissue engineering applications. Moreover, this study provides a new approach for the preparation of POx coatings, which is faster, easier, and more environmentally friendly in comparison to traditional grafting methods or plasma-assisted polymerization [3, 4].

This work was supported by Operational Programme Research, Development And Education - Project „Postdoc@MUNI“ (no. CZ.02.2.69/0.0/0.0/16_027/0008360).

Keywords: poly(2-oxazoline), cold atmospheric pressure plasma, coplanar discharge, biological active coatings, cells adhesion

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PREPARATION OF CERAMIC NANOFIBERS BY ELECTROSPINNING PROCESS AND PLASMA TREATMENT

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Abstract

In this work, the electrospinning process was used for the preparation of ceramic nanofibers from PVA/$Al(NO_3)_3 \cdot 9H_2O$ precursor solutions. Six different polymeric solutions were prepared for spinning. Each solution had different weight concentration of PVA/$Al(NO_3)_3 \cdot 9H_2O$ respectively. Precursor solutions were mixed at 80 °C over the night by magnetic stirrer till complete homogenization. Applied voltage varied according to concentration of solution from 45–60 kV. Distance between electrodes was fixed to 140 mm. Spinning was performed in ambient air, temperature and humidity between 40-60 % RH. Plasma process was held in experimental reactor equipped by a non-isothermal source of plasma (DCSBD electrode). Experiments were done with input power 400 W to electrode at air with flow of gas 5 mL/min. Samples were treated by plasma for 10 minutes before calcination. The calcination process was studied in 100, 250 and 1000 °C temperature steps. The final alumina fibres were obtained by calcination in furnace at 1000 °C with the heating rate 9 °C/min. Obtained calcinated nanofibers were analysed by ATR-FTIR analysis, scanning electron microscopy and EDX analysis.

Keywords: electrospinning, alumina, nanofibers, DCSBD plasma

PREPARATION OF AL_2O_3 NANOFIBERS BY THERMAL CALCINATION WITH LOW TEMPERATURE PLASMA PRE-TREATMENT

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Abstract

Inorganic submicron fibers (ISF) are typically produced by 2 step process. First, metal-organic fibers are made, usually by spinning techniques. These fibers consist of base polymer, which server as matrix, and metallic precursor, typically alkoxides or salts. The second step is thermal calcination, where polymer is removed and ceramics is formed, as the effect of high temperature. Exact time and temperature varies depending on the desired morphology and crystal phase [1]. While production of metal-organic fibers is relatively fast and cheap, the second step is much more time and energy consuming.

To reduce the time needed for thermal calcination, we studied the possibility to use low temperature plasma generated by Diffuse Coplanar Surface Barrier Discharge (DCSBD) on metal-organic SF as a pre-treatment before thermal calcination. Plasma serves as chemically active environment with high levels of reactive oxygen (ROS) and nitrogen species (RNS). This environment has proved to be effective in removal of base polymer, which can significantly reduce the time needed for thermal treatment of fibers [2].

The goal of our work is to explain processes that occur during interaction of plasma with metal-organic fibers and find ideal conditions for plasma pre-treatment to reduce

time and energy required for production of ISF. We investigated effects of pre-treatment on $Al(NO_3)_3$/PAN (polyakrylonitrile) fibers in N_2, O_2, synthetic air and laboratory air plasma. Significant removal of base polymer can be achieved in 10 minutes. Results showed highest rate of polymer removal in nitrogen plasma. We compared effects of plasma powered by 400 W at 14.6 kHz and 600 W at 26.9 kHz and found the latter more efficient. Observed increase in efficiency at higher input power and frequency was not caused by increase in temperature. Experiments conducted at elevated temperatures up to 120 °C using 400 W power supply did not show significant change. Thermal calcination of pre-treated samples caused less damage to the fibrous morphology when exposed to high heating rate (up to 50 °C/min) compared to untreated samples.

Keywords: plasma assisted calcination, inorganic fibers, DCSBD, alumina fibers

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TOPIC 2

FLEXIBLE ELECTRONICS

NANO- AND BIO-APPLICATIONS OF PLASMA TO THE RAPID MANUFACTURE OF FLEXIBLE AND PRINTED ELECTRONICS

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Abstract

Prevailing modes of the manufacture of electronics based on silicon fail to meet the requirements of the steps involved in low-cost fabrication. Rapid and low-cost roll-to-roll manufacture – the future of commercialization for flexible and printed electronics – requires flexible and low-cost substrates such as PET, PEN and, more recently, green materials such as nano-paper. The temperature at every single fabrication stage is crucial with such materials and cannot exceed a certain threshold, generally 150 °C or less. Furthermore, the time spent at every single fabrication stage is also important and should be short as possible to minimize the total duration of the roll-to-roll manufacture. Low-temperature plasma can, therefore, provide an excellent way forward for future manufacturing methods.

This contribution presents a number of different applications of low-temperature atmospheric plasma treatment in the field of flexible and printed electronics. Firstly, the plasma pre-treatment of various flexible substrates is demonstrated as an

extremely efficient tool before inkjet printing of functional coatings. The plasma treatment of polyethylene terephthalate, indium-tin oxide and nano-paper resulted in excellent wettability and/or optoelectronic features on the plasma-treated surfaces. This allowed the inkjet printing of various functional inks based on anatase-TiO_2, ZnO, graphene oxide and graphene oxide@TiO_2. Secondly, the plasma post-treatment of inkjet-printed films is crucial to the removal of organic moieties and consequent improvements in the photo- and catalytic performance of such films. The low temperature of the plasma and rapid treatment times, in the order of 1–10s, enable the integration of plasma processing into roll-to-roll manufacture, a significant step forward in commercial viability within the emerging field of flexible and printed electronics.

This presentation provides examples of:

a) rapid (<2 s) low-temperature plasma processing of nano-cellulose paper as a sustainable and biodegradable substrate for flexible and printed electronics,

b) rapid (<2 s) low-temperature plasma processing of indium-tin-oxide electrodes as a replacement for time-consuming chemical treatment before deposition of PEDOT:PSS in a p-i-n perovskite solar cell,

c) rapid (<1 min) low-temperature plasma processing of a mesoporous anatase-TiO_2 photoanode and its application in an n-i-p perovskite solar cell,

d) rapid (<1 min) low-temperature plasma hydrogen plasma processing of graphene oxide electrodes for detection of small biological molecules,

e) large-area, flexible, inkjet-printed photocatalyst on PET foil for efficient waste water and marine water treatment.

Keywords: plasma treatment, inkjet printing, perovskite solar cell, water cleaning, sensing

ATMOSPHERIC PRESSURE PLASMA TO TUNE PEROVSKITE SURFACE PROPERTIES FOR ENHANCING THE PERFORMANCE OF SOLAR CELLS

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Abstract

Perovskite solar cells (PSCs) have received great attention due to their potential for producing low-cost and high-efficient devices. PSCs are technologically attractive for many reasons: they can be deposited from solution over large areas and can be integrated into roll-to-roll manufacturing techniques. They are compatible with fabricating on a wide range of materials including flexible materials. Within a decade, PSCs reach a power conversion efficiency (PCE) of up to 25 % mainly due to a wide range of procedures such as perovskite film growth, compositional and interface engineering [1, 2]. Surface properties of perovskite films including morphology and chemical composition are among the main parameters to have a great impact on the performance of PSCs [3, 4]. An atmospheric pressure plasma (APP) is introduced to modify the surface properties of perovskite films. We used different gasses for the surface engineering of the perovskite layers. This approach allows for the rapid processing of the perovskite films which is especially important in the context of efforts to find a rapid and low-cost procedure for the surface modification of the perovskite layer.

APP treatment of perovskite films, presented herein, can be divided into two different processes. (i) ambient air and nitrogen plasmas were applied to the thermally annealed perovskite layer before deposition of the fullerene passivating layer. The results demonstrate that plasma treatment is a promising technique for controlling

surface composition and optoelectronic properties of perovskite layers and resulted in the enhanced performance of PSCs. (ii) the challenges of time-consuming perovskite deposition are avoided herein by the employment of diffuse and streamer-free hydrogen plasma (H_2 plasma) treatment instead of thermal annealing. Fig. 1 illustrates the steps in thermal annealing and H_2 plasma-assisted deposition of perovskite films.

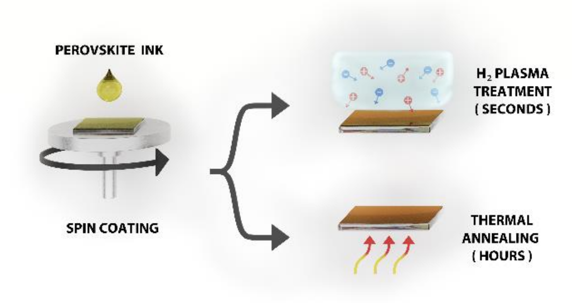

Fig. 1: Schematic of spin coating and subsequent H_2 plasma treatment compared with regular annealing of the perovskite film.

Keywords: perovskite, atmospheric pressure plasma, surface treatment, composition, morphology

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TOPIC 3

PLASMA DISCHARGES and SOURCES

FLEXIBLE CERAMIC SUBSTRATES FOR USE AS DIELECTRIC BARRIER LAYER

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Abstract

Dielectric barrier discharges are one of the most used tools for surface modification in modern industry. Dielectric barrier discharges can operate in atmospheric pressure and ambient air. Those properties make them significantly cheaper to use in industrial conditions then low-pressure discharges with similar effects on treated materials.

Thin flexible self-supporting ceramics are new promising material that can outperform dielectric barrier layers from glass and polymers, mainly in chemical and physical properties. In presented work, we study closely electrical parameters of alumina-based ceramics that has been enriched by chosen elemental dopant (Fe, Ce, Cr, Mg) to ensure suitable electrical parameters without compromising structural strength to open the possibility of creating thin and flexible ceramic layer. Our experiments mainly consist of precise electrical measurements to estimate ignition, working and quenching voltages. However, we have complemented our study with morphological imagining to compare obtained results with surface roughness and to discuss solubility of used materials in alumina matrix.

This research has been supported by the project CZ.1.05/2.1.00/03.0086 funded by the European Regional Development Fund, project LO1411 (NPU I) funded by the Ministry of Education, Youth, and Sports of the Czech Republic and project 18-05478S of the Czech Science Foundation

Keywords: dielectric barrier discharge, measurement automatization, material characterization, dielectric barrier, ignition voltage

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HV GENERATORS FOR DCSBD DISCHARGES AND THEIR PROPERTIES

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Abstract

The most common power supplies for DCSBD discharges are HV power supplies with alternating output in the range from 1kV to 10kV in the frequency range from 10kHz to 100kHz. The most common scheme of such an HV power supply consists of two parts: generator and HV transformer. The amplitude of the output voltage from the generator is of the order of distribution voltage. Therefore it is necessary to introduce an HV transformer in the circuit. HV transformers need higher quality isolation layers between coils due to HV output. This however highly influences the resulting coupling coefficient, e.i. HV transformers are leakage transformers. The main disadvantage of such transformers is the decreasing output voltage with increasing current into the load. Secondly the DCSBD discharges are mainly capacitive, which limits the value of the voltage gradient on the load. We can eliminate both negative effects, e.g. leakage voltage and limited voltage gradient, by using such construction as an LC resonance circuit. Then the output voltage of the HV transformer can be much higher than the output voltage given simply by multiplying input voltage by the turns ratio.

The LC resonance circuit construction allows us to change the amplitude of the output voltage (and the power) by changing the frequency of the input voltage with respect to the resonance frequency given by the leakage inductance of the HV transformer and the capacity of the load (DCSBD discharge). The closer frequency to the resonance frequency means the greater power to the load. However, greater power into load increases the effective capacity, and therefore it is necessary to satisfy the condition

that the working frequency is higher than the resonance frequency. Otherwise, it would not be possible to reach a smooth change of power.

We developed a new power supply for studying the discharges with the generator discussed above. However, we modified such a generator by tunable duty, tunable bus voltage or their combination. The main advantage of these new features is the ability to change the output power at a constant frequency, which is crucial for discharge diagnostics.

This new power supply is currently used for studying discharges on ceramics with different dopants with various concentrations. We investigate the influence of ignition and quenching voltage on the concentration of different dopants, thicknesses of the ceramics, and the electrode gaps.

This research has been supported by the project CZ.1.05/2.1.00/03.0086 funded by the European Regional Development Fund, project LO1411 (NPU I) funded by the Ministry of Education, Youth, and Sports of the Czech Republic and project 18-05478S of the Czech Science Foundation

Keywords: dielectric barrier discharge, measurement automatisation, material characterisation, dielectric barrier, ignition voltage

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RC-PROBE AND PEAKS SUPPRESSION IN DBD VOLTAGE MEASUREMENTS

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Abstract

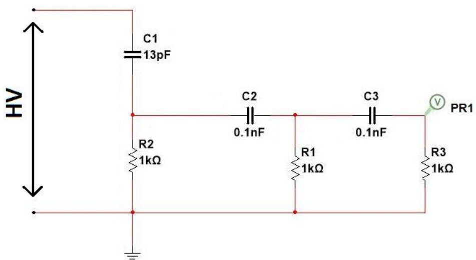

Fig. 1: Scheme of the RC-probe [2].

We show and describe the RC-probe for safe detection of current/voltage peaks coming from SDBD (DBD in general). To know the precise position of peaks is important for several reasons. For starters we can determine the precise time of the discharge ignition or we can work with statistics of peaks occurrence during the period. Current peaks can be best viewed by current probe discussed e.g. in [1]. The use of current probe is, however, very risky when dielectric breakdown of the ceramic barrier may appear. Such breakdown would lead to oscilloscope destruction. Therefore we propose a new RC-probe (see Fig. 1) based on RC differentiators [2].

The RC-probe is designed to suppress low-frequencies and pass high-frequencies. The probe consists of three RC differentiators, where the first needs to have an HV capacitor C1. In combination with resistor R2 in series it suppresses the low

frequencies (~10kHz) and protects the rest of the low voltage part of the probe from HV in the HV circuit. Next two RC-differentiators supress low-frequency part under the detection level of the oscilloscope. The signal measured on oscilloscope by probe PR1 is just flat signal and peaks coming from current representing individual filaments.

There is, however, one issue. We use HV power supply based on leakage HV transformer and generator. The voltage output of this generator has rectangular modulation. This, however, causes small voltage peaks on the HV output of the HV transformer and these can be viewed by the RC-probe. We need to suppress these peaks and to do it we use LC circuit between generator and HV transformer. The effect of LC circuit is to blunt the sharp rising edge of the voltage profile by the time constant of LC circuit.

These ideas allow us to be able to correctly capture the first current peak and therefore to capture the ignition voltage. The simplicity of the method allowed us to automate whole measurement and produce a large statistical samples of data.

Keywords: voltage measurements, RC-probe, voltage and current peaks

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TIME DELAY OF LOW-ENERGY ELECTRICAL BREAKDOWNS IN WATER AND PLASMA ACTIVATION OF WATER BY DIFFERENT PLASMA SOURCES

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Abstract

Plasma generated in and in contact with water become independent field of science. Due to its ability to produce chemically active species, it can find use in contaminated water treatments such as toxic organic compound removal or bacteria inactivation [1, 2]. Secondary products such as UV light or pressure shockwaves can be beneficial as well [3]. This contribution primary deals with generation of low-energy electrical breakdown in low-conductive water and its time delay. Time delay length (or distribution) is affected by many parameters like conductivity, temperature, flow speed etc. Time delay response on increased conductivity (Fig. 1) and temperature suggests, that mechanism of low energy breakdowns is independent (or not strictly bounded) to Joules heating of liquid.

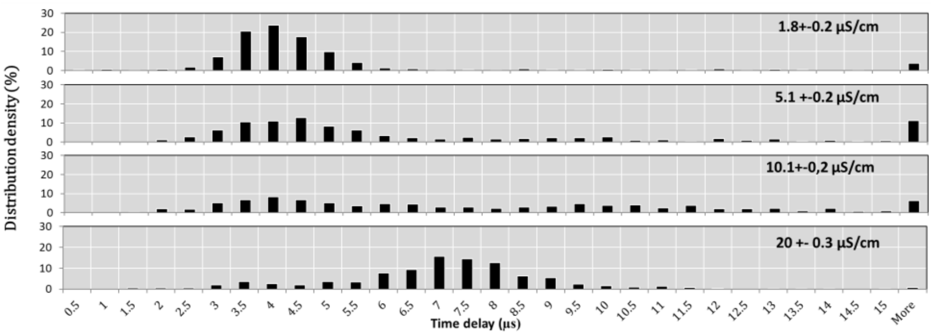

Fig. 1: Effect of conductivity on time delay distribution. Conditions: electrode spacing 0.5 mm; voltage 20 kV, temperature 24 °C.

In addition we also focus on the generation of discharge in water using two electrode configurations to study the parameters of plasma activated water (PAW) Preliminary investigation has shown that the atmospheric plasma (Fig. 2a) in contact with water has higher impact on change water parameters (such as conductivity or pH) than the plasma generated directly in the water (Fig. 2b). Further colorimetric experiments are planned to reveal chemical activity and evaluate potential application use of mentioned plasma sources.

This work was supported by the grant agency VEGA under the contract No. 1/0930/17.

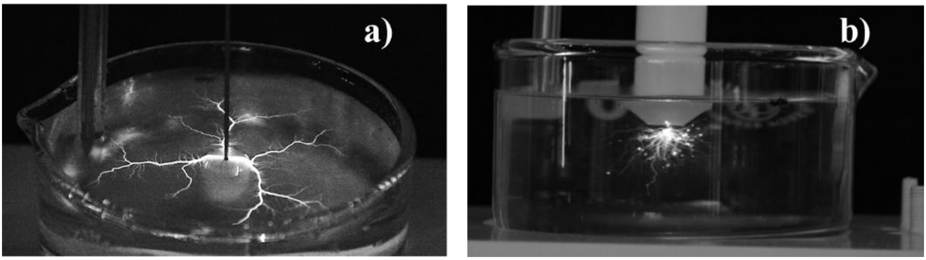

Fig. 2: Atmospheric discharge on surface of water (a) and direct water discharge (b).

Keywords: electrical breakdown, water, time delay, plasma activation

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TOPIC 4

BIOAPPLICATIONS

POSSIBILITIES OF DCSBD PLASMA APPLICATION IN AGRICULTURE: GERMINATION IMPROVEMENT AND SURFACE DISINFECTION

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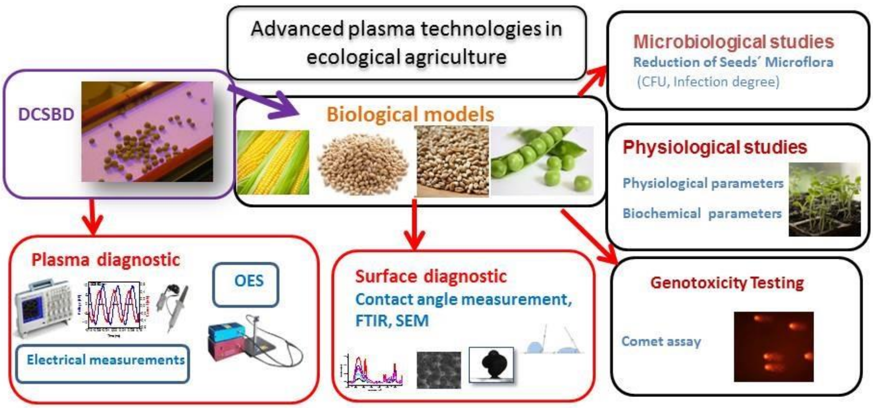
Abstract

Currently is research in the field of applied plasma physics intensively focused on the study of plasma application in agriculture to improve the germination and growth parameters of plants seeds [1, 2]. Due to the high reactivity of the plasma environment it is used also in the biological decontamination and sterilization of surfaces of plant seeds, crops, spices, dry fruits and food. In our research cold atmospheric pressure (CAP) plasma generated in the ambient air by Diffuse Coplanar Surface Barrier Discharge (DCSBD) was used [3]. This technique, both economical and environmentally friendly, is very suitable for in-line technology; without any vacuum devices or expensive gases. Our study was focused on the comparison of plasma treatment and application of chemical fungicide used against seed-borne phytopathogens (Fusarium culmorum) on the surface of wheat and barley grains. CAP treatment of seeds led to increased surface wettability, which helps better germination. Plasma surface treatment of the seed and subsequent application of fungicide was more effective than using each of them individually. An appropriate combination of plasma treatment time and chemical fungicide dose can significantly reduce the use of harmful chemicals, while stimulate germination via plasma treatment. We investigated the

effect of plasma treatment to estimate the optimum plasma exposure time and to determine the interval for safe use of plasma also. The DNA damage of pea seedlings was studied by the method of alkaline comet assay and the negative conditions for the seedlings were simulated using the toxic concentrations of zeocin. It has been shown that CAP plasma has positive effect on decrease of the DNA damage of pea seedlings in all used exposure times.

This work was supported by the Slovak Research and Development Agency under the contract No. APVV-16-0216.



Keywords: DCSBD plasma, seeds treatment, germination, decontamination, DNA damage

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THE EFFECT OF LOW-TEMPERATURE PLASMA ON DECONTAMINATION AND QUALITATIVE CHARACTERISTICS OF SPROUTS, NUTS AND SPICES

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Abstract

Fresh and dried food products intended for direct consumption required special strategies to ensure microbial safety and appropriate quality of food for consumers. Sprouts, nuts and spices belong to group of foodstuffs with proven health benefits. Fresh sprouts are highly nutritive food product, however the optimal environment for sprouting is frequently source of contamination by microorganisms. With the consummation of sprouts in raw form may pose a threat to human health [1]. Nuts are high in healthy fats and spices are used in food products for improvement of sensorial properties. Considering that these products are "ready-to-eat", various approaches have been studied to eliminate bio-contamination, mainly application of high temperature or chemicals. Nowadays, advanced physico-chemical processes were studied to ensure safety of sprouts, such as ultrasonication, irradiation, or [2, 3] and also nuts and spices [4]. The low-temperature (LT) non-equilibrium plasma pays an increasing attention of research as the prospective alternative to high temperature or chemical processes for application in food decontamination [5, 6].

In our research, LT plasma generated by different plasma sources working at atmospheric (dielectric barrier discharge and plasma jet) and low pressure (radio-frequency capacitively coupled discharge) actuating by direct or indirect mode was studied for decontamination of different samples. Besides the decontamination effect

on sprouts (soya beans, lentils and mung beans), nuts (hazelnuts and peanuts) and spices (black pepper and allspice) also the changes in important qualitative characteristics after plasma treatment were analyzed, such as sensorial properties in spices, quality of oils in nuts and nutritional values in sprouts.

This work was supported by the Slovak Research and Development Agency under the contract No. APVV-16-0216 and by the Slovak Grant Agency VEGA No.1/0930/17.

Keywords: fresh sprouts, low temperature plasma, decontamination, qualitative characteristics

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INFLUENCE OF COLD ATMOSPHERIC PLASMA JET ON FOUR DIFFERENT YEAST SPECIES

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Abstract

Yeast infections are a serious health problem mainly because the provided treatment is often not effective enough. Therefore, we have focused on the use of cold atmospheric pressure plasma as a potential alternative method for the treatment of yeasts [1–3]. In this work the effect of non-thermal atmospheric pressure plasma jet on four different yeast species; *Saccharomyces cerevisiae, Schizosaccharomyces pombe, Candida parapsilosis, Magnusiomyces magnusii* was investigated. Two different approaches were compared for the plasma treatment of the yeasts. The first approach was indirect treatment by plasma activated water (PAW) and the second one was direct exposure of the plasma to the distilled water or liquid culture medium involving the yeasts. Treatments were carried out using an Argon plasma jet driven by a 13 kV sinusoidal high voltage with a frequency of 5 kHz, as show in Fig. 1. Flow rate of Argon was 3 SLM. The treatment time in both approaches was 5, 7 and 10 min. Survived yeasts after the treatments were visually analyzed and compared with controls. The best results were observed in the case of the direct treatment of the yeasts in the distilled water. In this approach, we observed a reduction of the survival vs the treatment time even at the highest concentration of all species (10^6–10^7). Time evolutions of conductivity and pH of PAWs were investigated. There was an agreement

between the time evolution of these parameters and survival. *S. pombe* was shown to be the most sensitive yeast to almost all plasma treatment approaches.

Fig. 1: Plasma jet.

For statistical evaluation and confirmation of the reduction of the survival, we used optical density (OD) measurement. By this way, the reduction of the survival vs the treatment time was detected for *S. cerevisiae*. We need to detect it for other specious by OD measurement later, or even staining and colony counting.

This work was supported by the Slovak Research and Development Agency under the contract No. APVV-16-0216 and by the grant agency VEGA under the contract No. 1/0930/17.

Keywords: cold atmospheric pressure plasma, argon plasma jet, yeast, plasma treatment

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OPTICAL DIAGNOSTICS OF DCSBD PLASMA FOR BIOAPPLICATIONS

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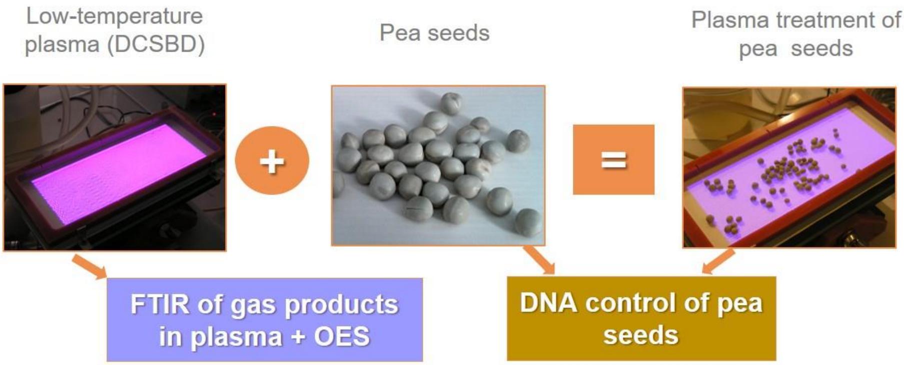
Abstract

Diagnostics of plasma from many aspects is very important in plasma application processes. It is necessary for a better understanding the mechanisms involved in the interaction of plasma with biological material, in our research with plant seeds. In this work, we used Diffuse Coplanar Surface Barrier Discharge (DCSBD) [1] as a source of low-temperature plasma for treatment of pea seeds with focusing on studying its changes in the level of DNA damage. Comet Assay method as a single cell gel electrophoresis [2] was used to investigate the DNA in eukaryotic cells of the pea seeds, what was the motivation to proceed optical diagnostics of the plasma. All experiments were provided in different working gasses (ambient air; O_2, N_2 and their mixtures in different ratios). Fourier Transform Infrared (FTIR) Spectroscopy showed the presence of reactive oxygen (ROS) and nitrogen species (RNS) in plasma. Optical Emission Spectroscopy (OES) gave us the information that plasma radiation is dominant for the second positive system of nitrogen $N_2(C^3\Pi_u \rightarrow B^3\Pi_g)$, but contain also other systems ($NO(A^2\Pi^+ \rightarrow X^2\Pi)$, $N_2(B^3\Pi_g \rightarrow A^3\Sigma_u^+)$) depending on working gas. Ambient air plasma is the most advantageous for the plasma treatment because it does not damage DNA. It could be the reason of the proper combination of radiation intensity, concentrations of ROS and RNS and water vapours present in ambient air.

This work was supported by the Slovak Research and Development Agency under the contract No. APVV-16-0216.



Keywords: DCSBD plasma, treatment of seeds, DNA, FTIR, OES

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EFFECT OF PLASMA TREATMENT ON SEEDS BEFORE COATING WITH AGROCHEMICALS AND ITS INFLUENCE ON SEEDS DUSTINESS

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Abstract

The aim of this research was to optimize a multi-hollow surface dielectric barrier discharge (MSDBD) to modify the seed's surface properties and to assemble a device for measuring the dustiness of the seeds coated with agrochemicals. Seeds of corn, parsley, pea, and wheat were examined for the effect of plasma on the dustiness of seeds. Dustiness of seeds is an essential indicator reflecting the quality of agrochemicals' adhesion on seeds. Therefore, we have decided to build such a device to meet the real needs of companies. The device for measurement of seed's dustiness is based on the Heubach test method [1]. MSDBD in flowing air was used for experiments (Fig. 1a). Exposure times of plasma treatment varied in a range of several seconds to tens of seconds regarding the variety of seed. Optimization of plasma exposure time for each seed variety was the primary goal of this research. Germination tests of plasma treated seeds were carried out just for a control (Fig. 1b). An increase of germination was not the main purpose of this study. Method of incrustation was used for the coating of seeds with agrochemicals. Measurements of water imbibition of seeds were done on seeds of pea and maize [2]. Moreover, plasma treated seeds were analyzed with X-ray photoelectron spectroscopy (XPS) and scanning electron microscopy (SEM) [3]. Dustiness of plasma treated seeds decreased significantly

compared to the untreated seeds. The decrease of dustiness was most evident on the seeds of maize.

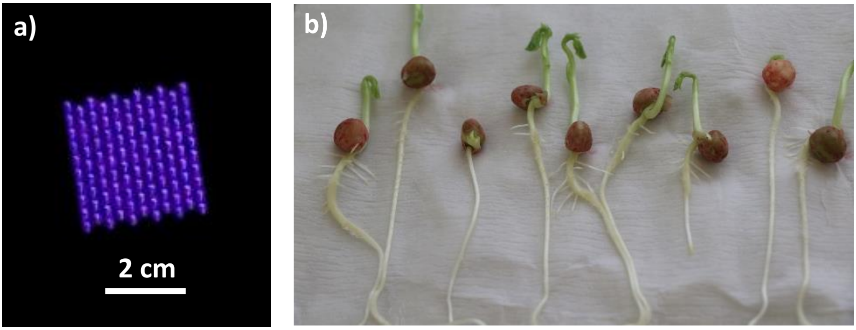

Fig. 1: a) Multi-hollow surface dielectric barrier discharge (MSDBD), b) seedlings of pea seeds during the germination test.

This research has been supported by the project TJ01000349, funded by the Technology Agency of the Czech Republic.

Keywords: low temperature plasma; seeds; multi-hollow surface dielectric barrier discharge; surface modification; bioapplication; dustiness

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MULTI-HOLLOW SURFACE DIELECTRIC BARRIER DISCHARGE FOR DECONTAMINATION

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Abstract

An advanced surface dielectric barrier discharges capable of generating diffuse plasma in flowing gas with high concentration of water vapour consisted of multi-hollow plasma sources powered by sinusoidal high voltage [1].

The bactericidal effect of plasma-activated gas on bacterial biofilm contamination on polypropylene non-woven textile surface was investigated. The decontamination effect was tested on *Escherichia coli*, *Pseudomonas aeruginosa*, (methicillin-resistant) *Staphylococcus aureus* and *Staphylococcus epidermidis*. The efficiency of short and long-time exposure was evaluated by standard microbiological cultivation (CFU plate counting) and analysis using fluorescence multi-well plate reader. The test was repeated at different distances of the contaminated sample from the dielectric surface. The properties of produced plasma-activated gas and generated discharge were also measured [2–5].

The bacterial biofilm decontamination efficiency increased with the exposure time and the input power of the high-voltage source. The log reduction of viable biofilm units varied with the increasing distance from the dielectric surface.

This work was supported by the project TG02010067 funded by Technology Agency of the Czech Republic. This research was also supported by the projects LO1411 (NPU I) and LM2018097 funded by the Ministry of Education, Youth and Sports of Czech Republic and by Grant No. 16–29916A funded by the Ministry of Health of the Czech Republic.

Keywords: multi-hollow surface dielectric barrier discharge, atmospheric pressure, water vapour, decontamination, bacterial biofilm

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TOPIC 5

NEW MATERIALS & NEW CHALLENGES

DEPOSITION OF COPPER HALIDE FILMS FOR OPTOELECTRONIC APPLICATIONS

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Abstract

Sequential pulsed chemical vapour deposition technique was used for deposition of copper (I) halide (CuHa) films, namely copper chloride (CuCl), copper bromide (CuBr) and copper iodide (CuI) in order to investigate their application to UV optoelectronics. For this work, a homemade atomic layer deposition (ALD) system was also developed. Copper (I) halides are wide-bandgap semiconductors with zinc-blende structure. Theirs high exciton binding energies give the possibility of stable, room temperature, UV emission which, together with high biexciton binding energies, enables optoelectronic effects such as bistability and four-wave mixing with the potential for new short wavelength devices. The films were deposited on various substrates (Si wafers, soda-lime glass, quartz and flexible polymers such as PI and PET) with various surface pre-treatment. It has been demonstrated that CuHa films can be deposited by sequentially pulsed vapour deposition processes using different solid and liquid precursors. While new precursors were used, it was necessary to find process parameters and conditions (timings, temperatures). The process optimization is still in progress, however, we have already shown there is set of precursors which is much easier to work with. Even, there are similar available precursors for chlorine, bromine and iodine so basically it could be possible to do CuCl, CuBr and CuI by essentially the same process.

In the last year of the project we focused on the characterization of the CuBr process. We have shown that CuBr can be deposited in the form of thin films or an array of nanocrystals (Fig. 1). The films were analysed by XRD, X-ray photoelectron spectroscopy (XPS), SEM, photoluminescence and spectroscopic reflectance [1, 2]. It was shown, that reflectance measurement can be used as a fast and simple means of film characterization. Capping layers of aluminium oxide were deposited in situ by ALD on several samples to avoid environmental degradation. The assumption of rapid degradation of the CuHa films at ambient conditions looks to be not significant as expected. It was observed that the air degradation of ALD-deposited CuCl films is much slower and clear characteristic CuCl structures were observed even after 3 months after storage at ambient conditions.

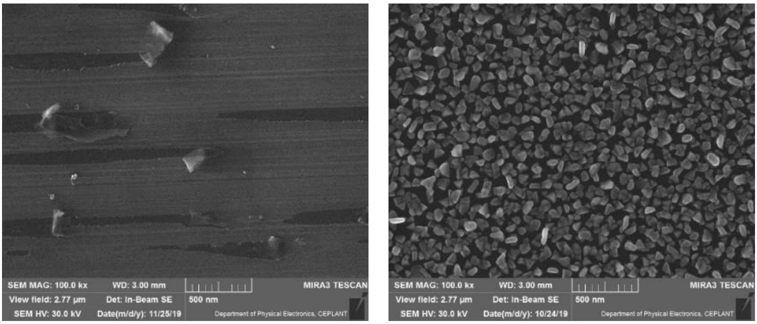

Fig. 1: CuBr can be deposited in the form of thin films (left) or an array of nanocrystals (right). The scratches on the left picture were done intentionally to highlight the film.

This work was supported by the Czech Science Foundation (No.17-02328S) and by the project LO1411 (NPU I) funded by the Ministry of Education, Youth and Sports of the Czech Republic.

Keywords: atomic layer deposition, copper chloride, copper bromide, copper iodide, nucleation, film growth, nanocrystals

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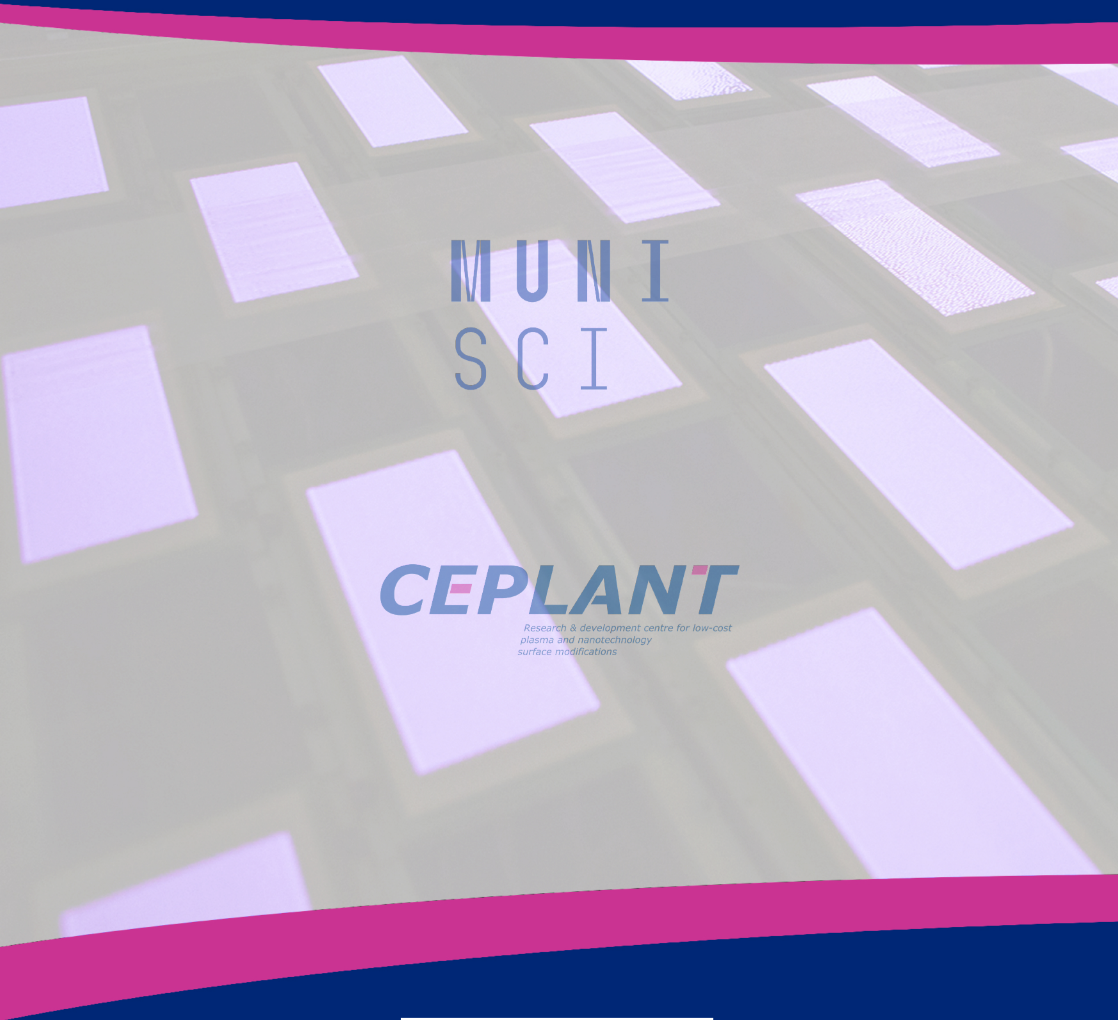

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