6th Int. Conference on Advanced Plasma Technologies

Workshop on Industrial Application of Plasma Solutions

11th to 18th December 2016, Siem Reap, Cambodia

Editor: Gregor Primc

Published by: Plasmadis Ltd, Teslova 30, 1000 Ljubljana, Slovenia

http://www.plasmadis.com

Ljubljana, December 2016

Atmospheric pressure discharges in tubes and pores

K. Hensel (1), M. Janda (1), Z. Machala (1), P. Le Delliou (2), P. Tardiveau (2) and S. Pasquires (2)

(1) Faculty of Mathematics, Physics and Informatics, Comenius University, Bratislava, Slovakia
(2) Laboratoire de Physique des Gaz et des Plasmas (LPGP), Universite Paris-Sud, Orsay, France

Atmospheric pressure non-equilibrium plasmas generated by electrical discharges are very attractive due to numerous applications, especially environmental and biomedical. The most common discharge types are coronas and dielectric barrier discharges, which form plasma in the volume or along the surface. However, discharges can be also generated inside cavities and pores of dielectrics placed between the electrodes. A number of hybrid configurations and devices have been developed and utilized in the past decades, e.g. micro-hollow cathode discharge, capillary plasma electrode discharge. Here, the focus is put on discharges in cavities of capillary tubes and porous foams. These discharges are interesting from the point of view of plasma assisted catalytic research that requires stable discharges plasma generation in contact with catalysts, their surface and porous structure. The physical properties of the discharge, conditions of their formation and propagation in tubes and foams are addressed with respect their geometry (e.g. length, diameter, pore size) and the applied voltage. The discharge in capillary tubes (diameter of 0.2-2 mm) was investigated in a single tube, as well as in a bundle of tubes. The single tube tests were essential to understand the mechanism of the discharge, while the tests with a bundle of tubes were performed to assess the stability, spatial homogeneity and chemical activity of the discharge. The spatial-temporal resolved propagation of the discharge front in the tubes was investigated and the discharge front propagation was found to be of order 10^7-10^8 cm/s and increasing with the diminishing tube diameter. Various configurations of tubes separated by one or two porous dielectric layers were tested. The changes of the discharge front propagation velocity as a function of thickness/porosity of the layer and amplitude/frequency of the applied voltage pulses was evaluated and compared. To assess the optimal conditions for the generation of stable plasma inside honeycomb-shaped monolith, tests with several tubes were performed. The properties of discharges generated inside the ceramic foams (pore size of 2 - 200 μm) were investigated and found possible only for a specific combination of the applied voltage and the pore size. The discharge inside the porous foams is repetitive short spark discharge that forms from the foregoing surface barrier discharge and its formation is accompanied with a sudden increase of the discharge current and light emission if compared to the barrier discharge. The mechanism of the discharge results from repetitive accumulation of charges on the resistive foam and their subsequent breakdown through the foam when their number exceeds a critical value. Temporarily resolved imaging reveals these discharges are randomly but homogeneously distributed both in time and volume of the foam. The two discharges were briefly subjected to the investigations of their plasma chemical effects, i.e. generation of O_3, oxidation of NO, and collection of PM and have proven their potential for exhaust treatment in a plasma-catalytic system.

Acknowledgments

This work was supported by Slovak Research and Development Agency APVV-0134-12 and VEGA 1/0918/15 grants.

Plasma activated water: effects for biomedical and agriculture/food applications and challenges of RONS detection

Z. Machala (1), B. Tarabová (1), K. Hensel (1), K. Kučerová (1), Z. Kovaľová (1), M. Janda (1) and P. Lukeš (2)

(1) Faculty of Mathematics, Physics and Informatics, Comenius University in Bratislava, Mlynská dolina, Bratislava 84248, Slovakia, machala@fmph.uniba.sk
(2) Institute of Plasma Physics of the CAS, v.v.i., Za Slovankou 3, Prague 18200, Czech Republic

Water and aqueous solutions treated by cold atmospheric plasmas – so called plasma activated water (PAW) are nowadays of the great interest for multiple applications in biomedicine and agriculture. Nonequilibrium air plasmas generate various radicals and reactive molecules commonly called reactive oxygen and nitrogen species (RONS: OH, H_2O_2, NO, NO_2, O_3, O_2-). These are transported through the plasma-liquid interface and induce formation of secondary RONS in water, H_2O_2, nitrites/nitrates NO_2-/NO_3-, peroxynitrites/peroxynitrous acid ONOO-/ONOOH, superoxide O_2-, O_3, or OH. Thanks to the combined effects of the plasma agents (electric field, electrons and ions, UV radiation, RONS) and the induced chemical changes in water, PAW has antimicrobial or therapeutic effects applicable in biomedicine or agriculture and food processing.

The bio-relevant effects of PAW can be enhanced when air discharges are combined with water electrospray, if compared with systems where discharge operates above water. The presence of the discharge in the spraying area allows for very efficient mass transfer of plasma-generated species into the micrometric water droplets. This underlines the dominant role of RONS among other plasma agents. However, metallic nanoparticles originating from the stainless steel needle electrode were detected in the water electrosprayed through transient spark air discharge and they can also contribute to the resulting bactericidal effect.

PAW antimicrobial activity decays in a few hours. In practical applications, the storage of PAW could be addressed by fast freezing of PAW, which preserves its antimicrobial activity for days and weeks.

The detection of RONS in the PAW is challenging due to the chemical instability of the detected RONS, or possible cross-reactivities of the used analytical methods. We tested and adapted colorimetric methods for special PAW conditions, such as colorimetric detection of H_2O_2, NO_2- and NO_3-, fluorescence spectroscopic detection of peroxynitrites, and indirect superoxide detection using superoxide dismutase. We also showed that established indigo blue colorimetric assay of dissolved O_3 might be misleading in PAW.

The discharge regime and gas/liquid characteristics determine the PAW composition and the consequent bio-relevant effects. In surface decontamination of biofilms, electrospray of water on the decontaminated surface significantly enhanced the antimicrobial effect, and vice-versa the sprayed PAW influenced the discharge and the chemical species produced. E.g. in low power corona discharges, water electrospray counter-intuitively increased O_3 production in both gas and liquid, which enhanced the biocidal effect. When changing the discharge regime from streamer to higher power spark, the gaseous products become dominantly NO_x, leading to significant concentrations of NO_2- and NO_3- in the PAW and practically no O_3.

Finally, preliminary results on cold plasma pasteurization of fruit juice (i.e. plasma activated juice) and enhancement of germination and plant growth by PAW demonstrate new potentials of PAW in food industry and agriculture.

Acknowledgements

This work was supported by Slovak Research and Development Agency APVV-0134-12 and COST Action TD1208.