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Measurement of reactive species in atmospheric pressure plasma systems used for creation of plasma activated liquids

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In recent years the topics of many different studies were focused on investigating the ability of Cold Atmospheric Plasma (CAP) treatments to produce Plasma Activated Liquids (PAL) that can be further used in different applications [1, 2]. During CAP treatments short-lived and long-lived reactive species generated in the plasma interact with the liquid target and after the treatment long-lived species are deposited and preserved in the samples. Physicochemical properties and concentrations of the reactive species produced in PAL depend not only on type of plasma source, type of discharge, but also significantly on CAP operating parameters, liquid target properties, amount of liquid etc. On the other side, for medical and agricultural applications tailoring PAL properties presents a crucial step as small charges in the RONS concentrations may induce different effects to biological systems. Therefore, an important step in investigation of plasma reactivity used in these applications is to obtain the link between plasma properties, concentrations of reactive species in the plasma and those in the produced PAL.
To illustrate potential variations in PAL properties, in Fig.1 we present results of measurements of Reactive Oxygen and Nitrogen Species (RONS) after treatment by using Microwave (MW) launcher with Ar as working gas. The results showed that increasing the flow of Ar as the working gas caused considerable differences in RONS concentrations and the changes did not follow the same trend during the flow increase.

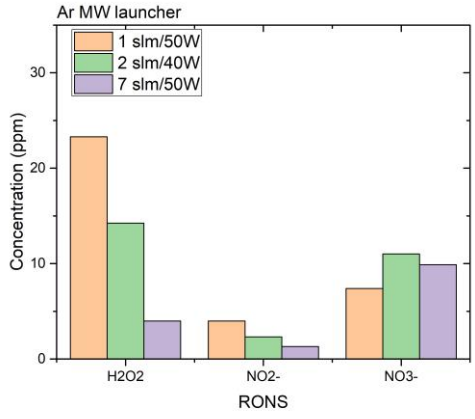

Figure 1. Measurements of RONS concentrations in PAW obtained from dH_2O for 3 treatment conditions (the gas flow and forwarded power). The treatment time was 10 minutes. Plasma was formed in Ar as working gas. Plasma plume was touching the liquid surface.

In this work we aim to establish dependence between reactive species measured in the plasma region and PALs properties. We will present results of PAL creation by using two types of plasma sources operating at atmospheric pressure to treat water and cell medium – MW launcher operating with Ar and Dielectric Barrier Discharge (DBD) source operating with addition of He. MW launcher was powered from a solid-state power supply at 2.45GHz and operated with different gas flows. The DBD source was operated at different powers and frequencies in kHz range, in air and He gas mixtures. Different plasma diagnostics was employed to obtain data on reactive species in the plasma – optical emission spectroscopy (OES) and mass spectrometry (MS). The MS analysis of reactive species was performed using HIDEN Molecular Beam Mass Spectrometer (MBMS) HPR60 device that can sample directly from ambient pressure. The device was employed in two operational modes: scan of complete mass spectrum and MID scan mode. In this mode, a real-time sensitive monitoring of radical evolution under both active and inactive discharge conditions was performed. To perform reliable measurements of long-lived reactive species in PAL we employed colorimetric methods in both water and cell medium and measured pH after the treatment.
OES of the MW discharge provided the information on the most prominent excited species formed: OH radical, N_2, N_2^+ and O atoms. Intensity of the emission lines was changing with input power and the gas flow. MS of DBD enabled to monitor production of NO, N_2O, NO_2 and O_3 depending on the operating conditions. We were able to select the operating parameters that supported the more intensive creation of O_3 or NO_x. Optical spectrometry provided information on the most intensive emission of excited species depending on the working gas.
In both systems we performed measurement of RONS concentrations in PAL by employing different colorimetric methods with respect to the liquid used. In the case of the cell medium, the existing colour of the liquid can prevent proper establishment of adsorbance and hence determination of RONS concentrations. So, we assessed the available colorimetric methods and selected the most reliable for specific liquid.

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References

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