Mass spectrometry measurements of the capillary single electrode helium plasma jet

D Maletić(*)[1], N Selaković[1], D Popović[2, 3], S Milošević[2], G Malović[1], Z Lj Petrović[4]

[1]*Institute of Physics, University of Belgrade, Pregrevica 118, 11080 Belgrade, Serbia*

[2]*Institute of Physics, Bijenička 46, 10000 Zagreb, Croatia*

[3]*N2 Applied, Dronning Eufemias gate 20, 0191 Oslo, Norway*

[4]*Serbian Academy of Sciences and Arts, Knez Mihajlova 35, 11000 Belgrade, Serbia*

(*) dejan_maletic@ipb.ac.rs

Plasma jets are simple in construction, but with unique and complex physical and chemical properties that have been in focus of extensive research in the last two decades. These nontermal plasma jets produce complex mixture of reactive species such as ions, radicals, electrons and RONS (reactive oxygen and nitrogen species) and have the potential to revolutionize material processing, biomedicine, agriculture and gas conversion. For example, plasma jets such as micro plasma jet, can be used to etch or deposit thin films on surfaces with high precision, making them useful in the manufacture of microelectronic devices. In biomedicine, plasma jets have been shown to have a range of therapeutic effects, including the ability to kill bacteria and promote wound healing [1]. Plasma jets are streams of highly ionized gas that are generated by an electric discharge. They typically consist of a plasma plume surrounded by a sheath of neutral gas. The electrons can reach high energies while ions and neutral molecules are close to room temperature. Low gas discharge temperatures are crucial in treatment of the thermo sensitive samples such as biological and polymer materials. Some of the recent applications are in production of plasma activated water (PAW) that has been used in sterilization of bacteria and in agriculture to promote plant growth [2]. Many different methods have been used for diagnostics of plasma jets such as optical emission spectroscopy, ICCD imaging, ultra fast imaging, electrical measuremts, mass spectrometry, laser diagnostics [3, 4, 5].

Here, we report mass spectrometry of atmospheric pressure plasma jet. The body of the jet is made of Teflon, the glass capillary (inner diameter of 1 mm and outer diameter 1.5 mm) and electrode copper wire (100 µm), see Fig. 1. The working gas was helium at a constant flow rate of 2 slm. The distance from the mass spectrometer HPR-60 was 15 mm in all measurements. We measure the current and voltage signals at the plasma jet electrode, while changing the output power of the high voltage power

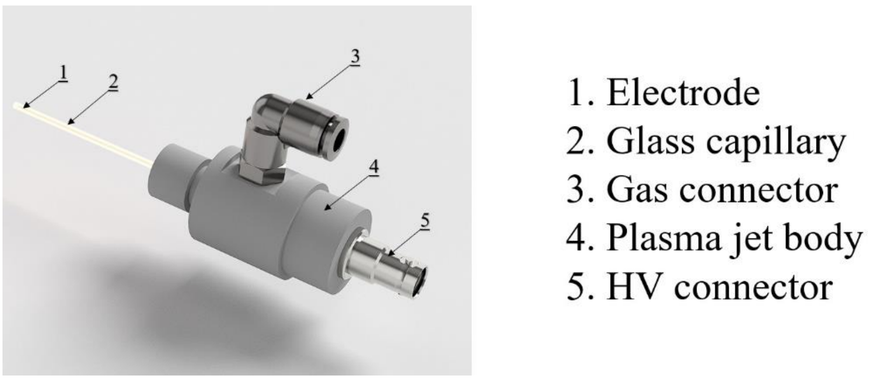

Fig. 1: Plasma jet

supply. Mass spectrometer was used to measure the neutrals and ions present in the plasma jet plume. Before each measurement we record ion energy distribution for the most abundant ion present in plasma

N_2^+ to confirm that the discharge is not entering the mass spectrometer. The maximum of the ion energy distribution should be below 5 eV and there should be no additional maxima at higher energies (not shown here).

In figure 2 we presented the yields for the positive ion mass spectra (SIMS+ mode) for the 5.7 Vpp and feeding gas flow rate of 2 slm. From the graph we can see that the plasma jet plume is rich with ion species that are needed in treatment of surfaces for cleaning or sterilization.

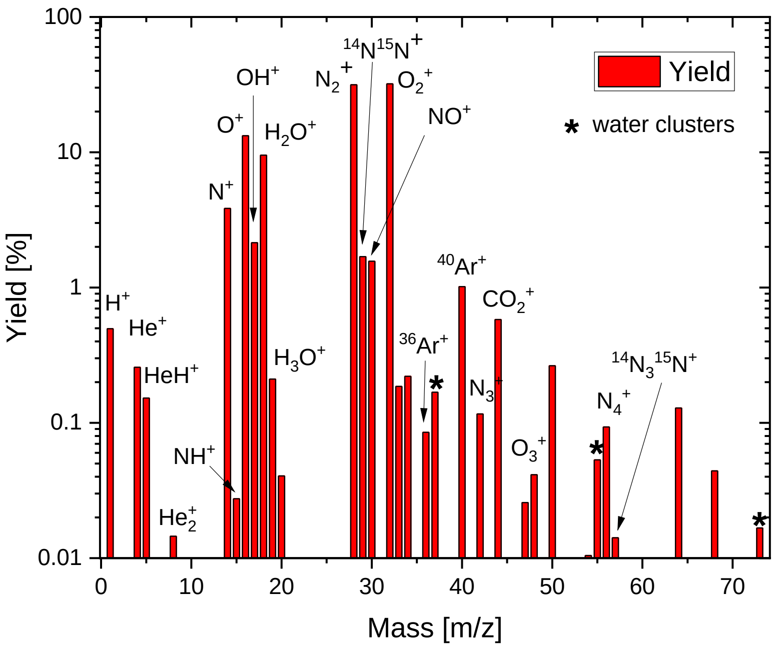

Fig. 2: Yields of the positive ions formed in plasma jet, 5.7 kVpp, 2 slm

In Figure 2 one can see mass spectrum of positive ions where the most abundant species are oxygen and nitrogen. The species formed by ionization of the working gas such as He^+, HeH^+ and He_2^+ are also significant.

Humidity in atmosphere influences production of OH^+, H_2O^+, H_3O^+ and appearance of water clusters $H^+(H_2O)_n$, which are shown in the image with an asterisk. The rich spectrum of positive ions obtained from the plasma jet indicates its potential application. The mass spectrometer technique itself is a powerful tool for monitoring and designing the spectrum itself.

Acknowledgment: This work was supported by MSTDI Republic of Serbia grant number 451-03-68/2023-14/200024. Z. Lj. P. is grateful to the SANU Project F155 for partial support. This work was supported by the project Adaptation of vegetables to new agrometeorological conditions in Slavonia (AVACS), KK.05.1.1.02.0004. The project was financed by the European Union from the European Regional Development Fund.

[1] E. H. Choi et al. *AAPPS Bulletin* **31** (2021) 10.
[2] N. Romanjek Fajdetić et al *Sustainability* **14** (2022) 16237.
[3] D. Maletić et al *Plasma Sources Sci. Technol.* **31** (2022) 025011.
[4] A. Stancampiano et al *J. Phys. D: Appl. Phys.* **51** (2018) 484004.
[5] J. Benedikt et al *Plasma Sources Sci. Technol.* **30** (2021) 033001.