Quantitative analysis of NO_2 generated in Atmospheric Pressure Plasma Jet using Ion Mobility Spectrometry

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Reactive oxygen and nitrogen species (RONS) play key roles in numerous biochemical, physiological, and pathological processes. Among them, species such as O_3, OH, NO_2, NO_3, N_2O_5, etc., can be efficiently generated utilizing atmospheric pressure plasma jets (APPJ) in Argon [1–4]. The controlled production of RONS by APPJ finds widespread applications in biomedicine for wound healing [5], cancer treatment [6], immune cell activation [7], surface treatment and sterilization [8, 9]. Various diagnostic techniques, including Fourier-transform infrared (FTIR) spectroscopy [10], chemical and semiconductive gas sensors [11, 12], have been employed for RONS detection.

The APPJ utilized in this study was developed at the Department of Experimental Physics, Comenius University Bratislava [1]. The Ar plasma jet was generated within a glass capillary with an internal diameter of 0.5 mm, employing a hollow needle to cylinder geometry configuration. A high voltage with an amplitude from 1 to 4 kV (0.09 to 1.2W) and a frequency of 9.45 kHz was applied to the needle. The flow rate of Ar (purity 4.6) was varied at 20, 50, 100, 150 and 200 mL/min.

The IMS employed for detection of NO_2 generated by APPJ and assessing electron transfer reactions between reactant ions (RI) $O_2^-.CO_2.(H_2O)_{0,1,2}$ and NO_2 was developed by MaSa Tech Company. The IMS is a rapid (milliseconds to seconds range) [13], highly sensitive (parts per billion to parts per quadrillion level) [14], good portable and powerful analytical technique useful in various fields [15]. Notably, NO_2 and other RONS can be detected in negative polarity mode.

The IMS spectra of the APPJ at discharge power ranging from 0.09 to 1.2 W and Ar gas flow of 100 mL/min are shown in the Fig. 1. The dominant peak with reduced mobility of 2.23 $cm^2.V^{-1}.s^{-1}$ represents RI. Peaks with reduced mobility of 2.50 and 2.38 $cm^2.V^{-1}.s^{-1}$ represent ions NO_2^- and $N_2O_2^-$, respectively. The ionization of neutral NO_x species was carried out using negative chemical ionization method, with RI. In the earlier study, was the IMS quantitative calibrated for NO_2 species [16]. The production of NO_2 generated in APPJ increased with increasing of discharge power (Fig. 1). The maximum NO_2 production of 5.3 ppm was observed at power of 1.2 W (4 kV) and Ar gas flow rate of 100 mL/min.

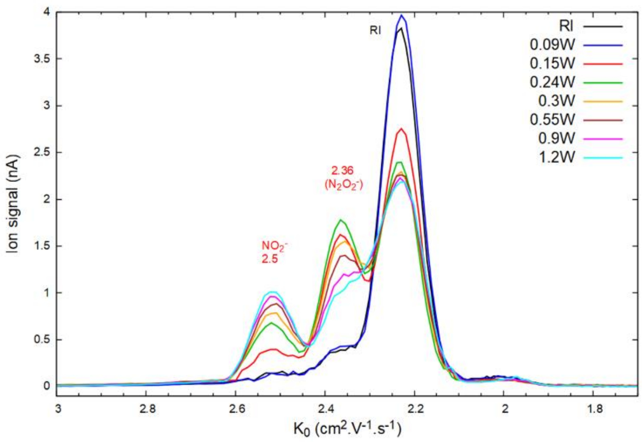

Fig. 1: The IMS spectra of the APPJ at discharge power ranting from 0.09 to 1.2 W and Ar gas flow of 100 mL/min.

The dependence of the concentration of NO_2 generated in the APPJ at different discharge powers, an Ar flow rate of 100 ml/min and different distances of the IMS from the APPJ is shown in the Fig. 2. The concentration of NO_2 slowly increased with increasing IMS-APPJ distance. The maximum NO_2 production (5.3 ppm) was observed at a distance 5 mm and decreased with further increasing IMS-APPJ distances.

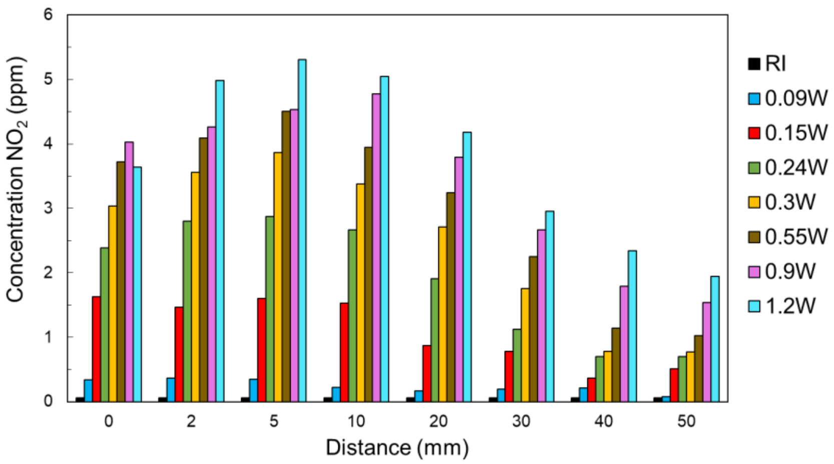

Fig. 2: Production of NO_2 generated in the APPJ at different discharge powers, Ar flow 100 mL/min and different distances of the IMS from the APPJ (0 – 50 mm).

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