Atmospheric pressure plasma as CO source for biomedical applications

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Abstract: In this work we developed a plasma source based on a Plasma Gun reactor able to generate small quantities of CO. The production fraction of CO molecules has been measured *ex-situ* by means of gas chromatography. We showed that the density is in the 100 – 10000 ppm range. The CO concentration can be controlled by varying the gas mixture and by tuning the applied voltage. In CO clinical application, the typical dose used is in the range of 100 -1000 ppm. It means that this plasma reactor is suitable as CO source for biological applications.

Keywords: CO source, biomedical applications, atmospheric pressure plasma, Plasma Gun, plasma jet

1. Introduction

Carbon monoxide (CO) is well known for its toxic effects at high doses. The effects of CO can be quantified via the percentage of carboxyhemoglobin (COHb) forms in the blood. The percentage of COHb in blood strongly depends not only on the percentage of CO in air, but also on the exposure time. However, CO is also naturally produced at cellular level, mostly via the catabolism of heme. At low doses, CO has therapeutic properties. Experimental studies found several positive effects of CO such as anti-inflammatory, vasodilatory and anti-apoptotic effects. It has also an influence on plants and promote the seed germination and increases the roots formation [1], [2].

In this context, non-equilibrium plasma at atmospheric pressure is an attractive *in situ* CO source, since it is able to create CO at low concentration from CO_2. This has the advantage to alleviate the risk related to CO storage.

Additionally, atmospheric pressure plasma can be used for biomedical applications. It has been demonstrated that plasma has antitumor and cell regeneration effects [3], [4]. The combination of plasma and CO could have then synergetic effects.

This contribution focuses on the challenge to develop a plasma reactor able to produce controlled small quantities of CO for biomedical applications.

2. Experimental set-up

The plasma reactor is based on a Plasma Gun device. The primary discharge is produced in a coaxial dielectric barrier discharge (DBD) reactor equipped with a quartz capillary tube. A schematic of this reactor is shown on Figure 1. Inside the 4 mm inner diameter tube is inserted a ring electrode connected to the high voltage, while a second ring electrode placed around the tube is connected to the ground. The two electrodes are separated by a 1 mm gap. The quartz tube is connected to a cylindrical cell of a 40 mm diameter and 40 mm high. A third electrode wrapped at the end of the cell is connected to the ground.

In this work, the device was powered by microsecond-duration voltage pulses from 10 to 20 kV with a repetition frequency between 1 kHz to 20 kHz.

The gas flow rate was set between 50 – 2000 standard cubic centimeters per minute (sccm) is used. The experiments were performed at atmospheric pressure in helium as buffer gas with small quantities of CO_2 varying ratios from 0.5 to 10%.

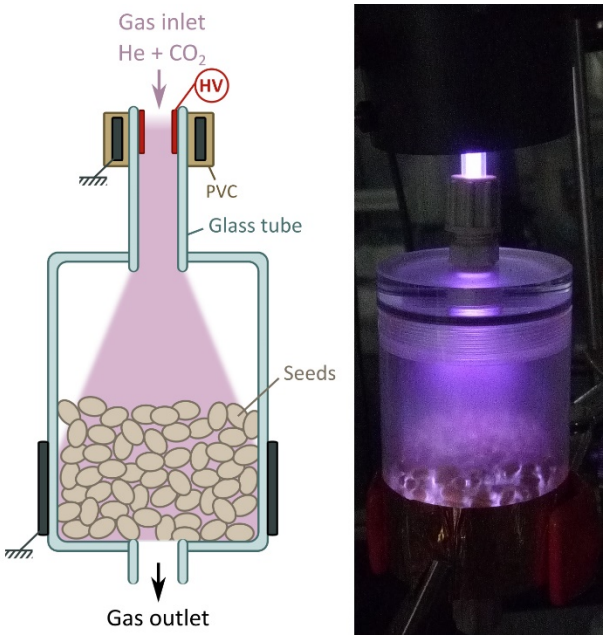

Figure 1: Schematic (left) and picture of the plasma reactor (right).

In order to mimic the biological application conditions, the cell was half-filled of wheat seeds (approximately 250 seeds).

The CO fraction in the effluent of the reactor is measured by an *ex-situ* gas analyser method with a gas chromatograph.

3. Results and discussions

The quantity of CO was measured as a function of the CO_2 percentage in the exhaust gas mixture. For the typical results plotted in Figure 2, the total gas flow was 500 sccm, the applied voltage was 15 kV and the repetition frequency 5 kHz. As it can be seen, only small quantity of CO_2 are necessary to form significant amounts of CO, but percentages higher than 1.0 % lead to a decrease of the produced concentrations.

The production lies in the 400 – 1200 ppm range and corresponds to the dose usually used in CO clinical applications [2], showing that this plasma can be suitable use as CO source for biomedical applications.

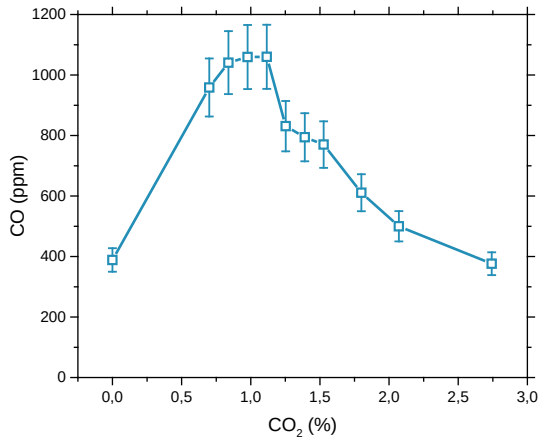

Figure 2: CO fraction as a function of the CO_2 percentage. The total gas flow is 500 sccm. The applied voltage is 15kV, and the repetition frequency 5kHz.

Figure 3 shows, in a log scale, the CO measured fraction in the gas effluent as a function of the applied voltage for 500 sccm of He and 1% of CO_2. In the present graph the trend follows a quasi-linear law indicating that the produced CO quantity increases according to an exponential-law.

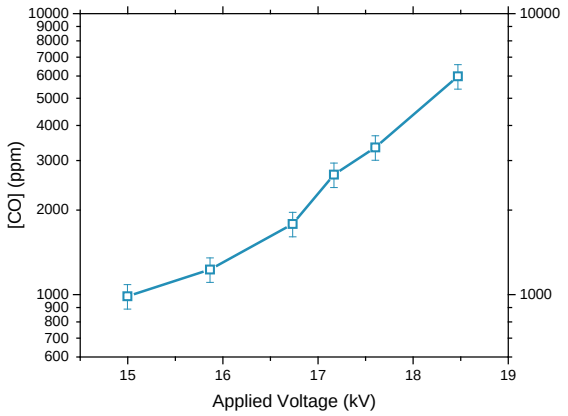

Figure 3: CO density as a function of the applied voltage in log-log scale. The gas flow is 500 sccm of He with 1% of CO_2 and the repetition frequency is 5kHz.

4. Conclusion

In the work we developed a plasma source based on a Plasma Gun reactor able to produce small quantities of CO ranging between 100 – 10000 ppm. The fraction of CO molecules has been measured ex-situ by means of gas chromatography. The produced CO fraction can be easily controlled by varying the gas mixture and by tuning the applied voltage.

In CO clinical application, the typical dose used is in the range of 100 -1000 ppm. It means that this plasma reactor is clearly suitable as CO source in that domain and for other biological applications.

5. References

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