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Electrical characterization of an air microplasma jet operated at a low frequency ac voltage

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Abstract In this work a small plasma jet is generated applying an ac high voltage (kV) of low frequency (50 Hz) between two disk-shaped electrodes with a hole in the center and separated by a centrally perforated dielectric material. A plasma jet emerges from the electrode system to the room air when a large air flow rate is passing through the holes, for inter-electrode voltage drops around 1 ÷ 3 kV. The electrical characteristics of the discharge, voltage and current were studied varying the applied voltage amplitude and the gas flow rate. It was found that the microplasma jet was stable during a long period of time and the gas temperature remained almost at room temperature. These characteristics make this discharge suitable for biological applications.

1. Introduction

Non-thermal discharges generated at reduced pressures in vacuum reactors have a well established, broad spectrum of applications in material science. Nowadays, usage of non-thermal atmospheric plasmas is studied with growing interest, as these plasmas provide a cheaper and more convenient alternative to low-pressure plasma technology. Another important advantage of using atmospheric plasmas is the possibility of processing materials which are not resistant to high vacuum. An attractive application of these plasmas is its utilization in removal and sterilization of bio-films and planktonic bacterial

The plasma generated by an electric discharge within a gas contains free electrons and ions, several active species (i.e. atomic or molecular radicals, O, OH and excited molecules) and energetic UV photons with well known sterilization properties. Several applications of this kind of plasmas in the biology field were performed using a RF discharge called “plasma needle”, with a great variety of studies including surface sterilization and bacterial removing and deactivation. *In vivo* applications were also studied, oriented to wound disinfection and dental cavities sterilization without drilling [1,2,3,4]. Due to the great importance and variety of applications a great amount of work appeared recently concerning biological applications of non-thermal plasmas, where it was studied the optimization of the discharge parameters [5], the dependency in the gas flow [6] and its capacity for bactericidal applications [7,8,9]. The majority of the devices employed for biological purposes work with noble gases or a mixture of them, due to the easiness of producing the discharge, with a small amount of O₂ or air which produces most of the active species. Nevertheless, Lu et al. [10] presented a

stable discharge in pure air achieving a more reactive plasma. Recently, non-thermal plasmas at atmospheric pressure called “plasma jet” or “microplasma jet” that can be applied to biological applications were developed using a great variety of ac-sources, which are as efficient as RF sources and less expensive [11,12,13].

In this work we present a small plasma jet generated by applying an ac high voltage (kV) of low frequency (50 Hz) between two disk-shaped electrodes with a hole in the center and separated by a dielectric material. A plasma jet emerges from the electrode system to the room air when a large air flow rate is passing through the holes, for inter-electrode voltage drops around 1 – 3 kV. The electrical characteristics of the discharge, voltage and current were studied varying the applied voltage amplitude and the gas flow rate. The plasma jet appearance and temperature were also studied.

2. Experimental set-up

A schematic of the experimental device used to produce the atmospheric plasma jet is shown in figure 1. The device consists in two electrodes with a hole of 1 mm diameter, through which air is flowing. The two electrodes are made of stainless steel disks of 20 mm diameter and 3 mm thickness attached to the surface of a centrally perforated dielectric disk (Teflon) of 1 mm thickness. The hole in the center of the dielectric disk is 2 mm in diameter.

The ac power supply is a commercially available transformer for neon light (25 kV peak to peak voltage, 50mA, 50 Hz) which is connected to a variable autotransformer (Variac) in order to allow voltage control. The air used was commercial analytic air ($\text{H}_2\text{O} < 5.0$ ppm/v, $\text{CO}_2 < 10.0$ ppm/v) and the flow could be varied up to 17 l/min.

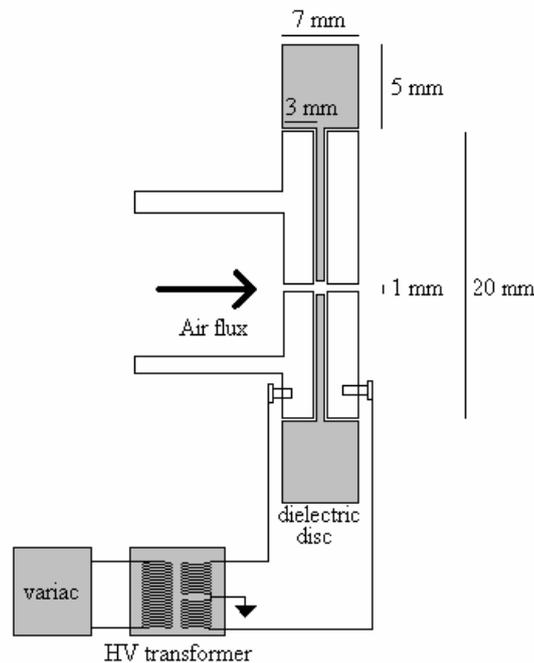


Figure 1. Schematic of the experimental set-up.

The electrical characteristics of the discharge and the appearance of the plasma jet were studied varying the applied voltage amplitude and the gas flow rate. The voltage V_{ag} between one of the electrodes and the grounded middle point of the transformer (i.e. half the electrodes voltage) was measured using a high voltage probe (1000x) connected to a digital Tektronix oscilloscope (70 MHz, 1GS/s), and the current I was measured using a commercial current transformer (2.5 V/A). Photographs of the microplasma jet were taken using a 10 Mpixel digital camera (exposure times of

1/8 s) and the microplasma jet average temperature was measured using a k-type thermocouple located inside the plasma jet. The air flow was measured using a stainless steel float flow meter.

3. Experimental results and discussion

Figure 2 shows a photograph of the device with the plasma jet emerging from the electrode system.

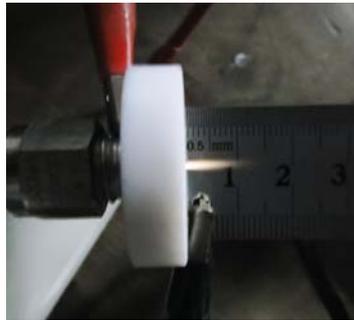


Figure 2. Photograph of the experimental device.

Figure 3 shows images of the microplasma jet operated in air for different open circuit voltage amplitudes ($V_{ag\ op}$) and a flow rate of 9.2 l/min. It was found that as the voltage decreases, the jet becomes shorter and less luminous. The discharge could not be maintained at $V_{ag\ op}$ values smaller than 5.5 kV.

The flow rate was varied between 4.7 to 13.5 l/min. Figure 4 shows images of the microplasma jet operated in air for different flow rates and $V_{ag\ op} = 10$ kV. The length of the plasma jet increase with increasing flow rate up to about 9 l/min, and with higher flow rates the jet becomes shorter. Jets longer than 1 cm were obtained for a flow rate of 9.2 l/min and $V_{ag\ op} = 10$ kV. The temperature of the jet measured with the thermocouple is close to room temperature. The plasma jet can be touched without any harm. Figure 5 shows the jet in contact with a human finger.

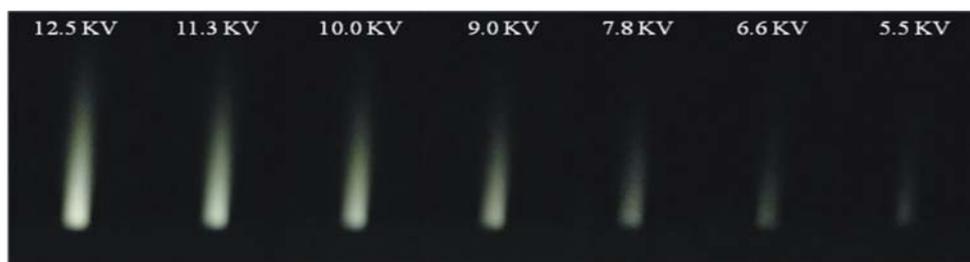


Figure 3. Jet photographs for different open circuit voltages of the transformer and a flow rate of 8.2 l/min.

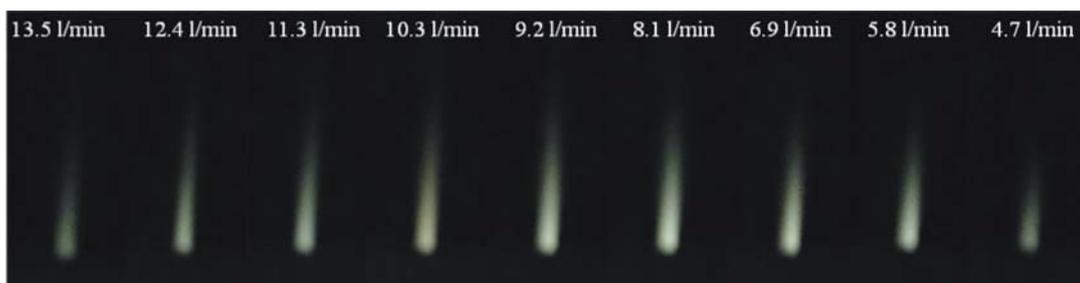


Figure 4. Jet photographs for different air flows and $V_{ag\ op} = 10$ kV.

Typical signals of V_{ag} and I taken during the discharge are shown in figure 6. The voltage of the discharge has a large amount of pulses with amplitudes of about 3 kV and duration around 150 ns for a flow rate of 9.2 l/min and $V_{ag\ op} = 10$ kV, reaching minima of some hundreds of volts.

The voltage pulses are accompanied of very short current peaks which can reach some amperes and last about 20 ns at the base of the pulse.

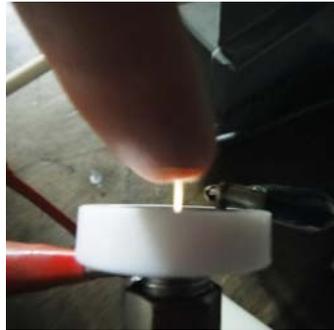


Figure 5. Photograph of a finger touching the plasma jet transformer.

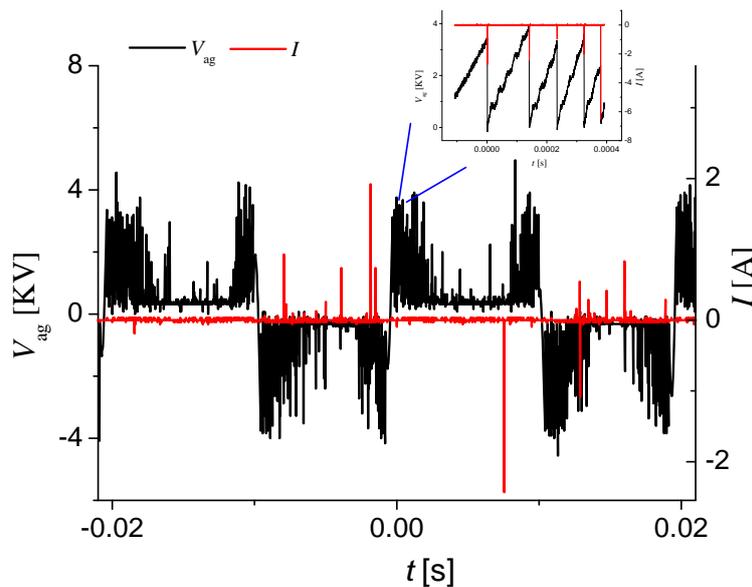


Figure 6. Typical voltage and current waveforms of the discharge.

Figure 7 shows a time scale expansion of the voltage signal for two different open circuit voltages of the transformer ($V_{ag\ op} = 12.5$ kV and 5.5 kV) and for an air flow of 9.2 l/min. It can be seen that as $V_{ag\ op}$ increases the pulse amplitude does not change, but the pulse train becomes shorter and the pulse frequency increases. The increase of this frequency with increasing values of $V_{ag\ op}$, can be appreciated in figure 8.

Figure 9 shows a time scale expansion of the voltage signal for two different air flows (air flow 13.5 l/min and 4.7 l/min) and a fixed open circuit voltage of $V_{ag\ op} = 10$ kV. It can be seen that the frequency of the peaks does not change, but the pulse number and amplitude increases, as the flow

increases. The increase of the pulse amplitude with the flow rate increasing can be appreciated in figure 10.

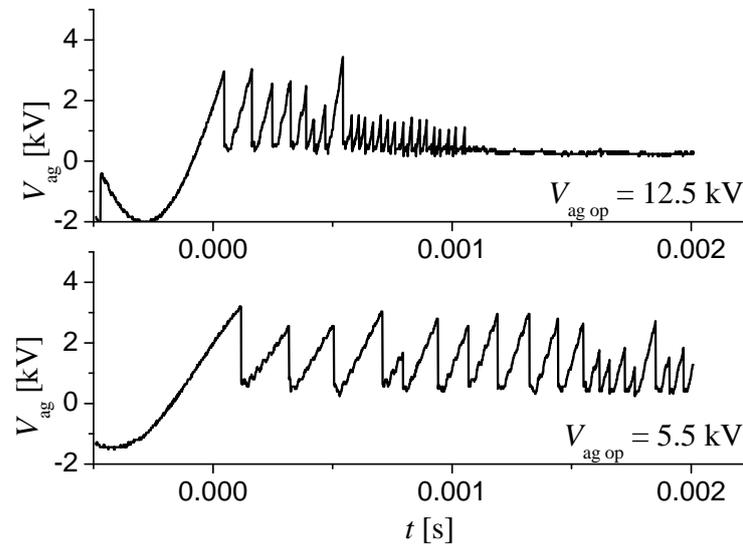


Figure 7. V_{ag} for the two extreme applied open circuit voltage values of the transformer, for a fix air flow of 9.2 l/min.

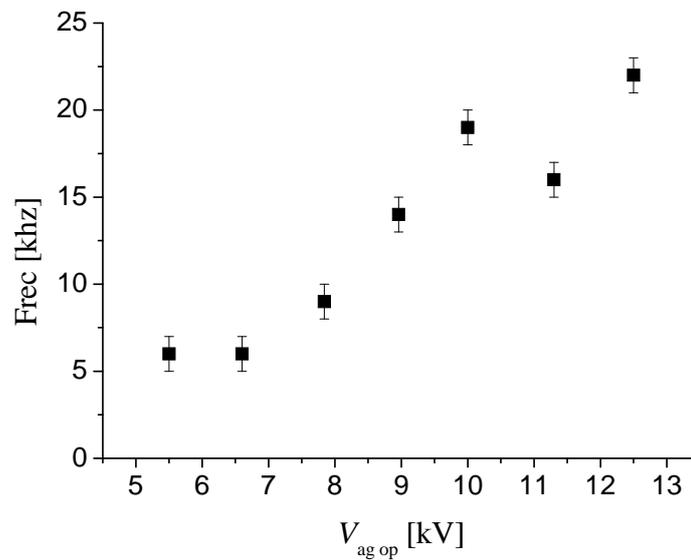


Figure 8. Peak frequency as a function of $V_{ac\ op}$.

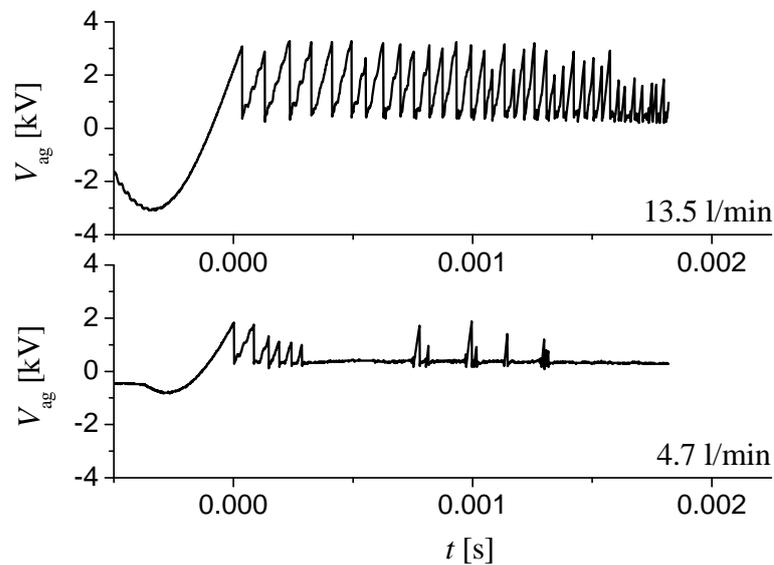


Figure 9. V_{ag} for the two extreme air flows, for a fixed open circuit voltage of the transformer at 10 kV.

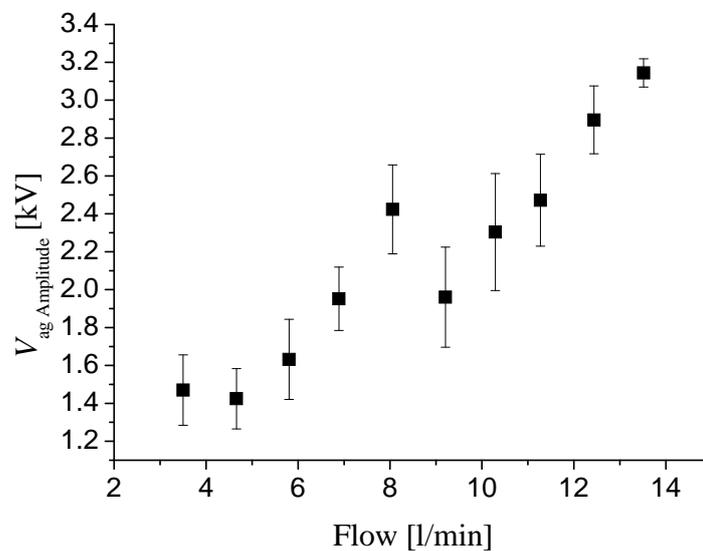


Figure 10. Pulse amplitude as a function of the air flow.

4. Conclusions

A stable microplasma jet of about one centimeter long was obtained within a pure air flow. The jet was formed at atmospheric pressure and room temperature and could be safely put in contact with human skin.

The voltage of the discharge is pulsed with pulse amplitude of a few kV, reaching minima of some hundreds of volts. The voltage drops are accompanied of very short current peaks which can reach

some amperes and last about 20 ns at the base. The pulse amplitude was found to be independent of the power source voltage and to increase with the air flow due, quite probably, to an increment in the pressure.

The frequency of the discharge pulses was independent of the air flow, and increased with the power source voltage. This is appreciated in the jet as an increment of the length and luminosity. The length and luminosity of the jet varied with the air flow and there was an optimum for each value of the power source voltage.

All these studies are directed to the achievement of an appropriate discharge configuration for the technological development of devices used for sterilization, bacterial removal and deactivation, and also for in vivo applications as wound disinfection and decontamination of dental cavities without drilling.

Acknowledgements

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References

- [1] Stoffels E, Flikweert A J, Stoffels W W and Kroesen G M W 2002 *Plasma Sources Sci. Technol.* **11** 383–8
- [2] Sladek R E J and Stoffels E 2005 *J. Phys. D: Appl. Phys.* **38** 1716–21
- [3] Sladek R E J, Stoffels E, Walraven R, Tielbeek P J A and Koolhoven R A 2004 *IEEE Transactions on Plasma Science* **32** 1540-3
- [4] Stoffels E, Sakiyama Y and Graves D B 2008 *IEEE Transactions on Plasma Science* **36** 1441-57
- [5] Simon A, Anghel S D and Papp J 2008 *Journal of Optoelectronics and Advanced materials* **10** 2077–81
- [6] Goree J, Liu B and Drake D 2006 *J. Phys. D: Appl. Phys.* **39** 3479–86
- [7] Lee M H, Park B J, Jin S C, Kim D, Han I, Kim J, Hyun S O, Chung K and Park J 2009 *New Journal of Physics* **11** 115022 (11pp)
- [8] Zhang X, Huang J, Liu X, Peng L, Guo L, Lv G, Chen W, Feng K and Yang S 2009 *Journal of Applied Physics* **105** 063302 (5pp)
- [9] Malovic G, Puac N, Lazovic S and Petrovic Z 2010 *Plasma Sources Sci. Technol.* **19** 034014 (7pp)
- [10] Lu X, Xiong Z, Zhao F, Xian Y, Xiong Q, Gong W, Zou C, Jiang Z and Pan Y 2009 *Applied Physics Letters* **95** 181501 (3pp)
- [11] Hong Y C and Uhm H S 2006 *Applied Physics Letters* **89** 221504 (3pp)
- [12] Mohamed A -A H, Kolb J F and Schoenbach K H 2010 *Eur. Phys. J. D* **60** 517–22
- [13] Anghel S D, Simon A, Papiu M A and Dinu O E 2011 *Rom. Journ. Phys.* **56** 90–4