Characterization of hybrid gas-liquid Dielectric Barrier Discharge plasma reactors for water treatment
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1. Experimental and diagnostic setup

In this work pin-to-water and plane-to-water plasma reactors for an enhanced peroxone process in water treatment, are studied. Electric and spectroscopic characterization of the discharges has been carried out in different operating conditions.

Above the liquid surface and in contact with it an atmospheric pressure dielectric barrier discharge (DBD) had been induced. A Petri dish, with a diameter of 90 mm filled with 20 ml of tap water is placed above a polished stainless steel plate connected to a high voltage source. In the pin-to-water geometry the ground electrode is a stainless steel rod. In the plane-to-water configuration the ground electrode is a 25 mm x 25 mm copper strip covered by a 50 mm x 50 mm x 3 mm ceramic slab. Air gap is fixed at 5 mm because this is the smallest value of it that guarantees plasma ignition avoiding the attachment of the water onto the ground electrode due to the Taylor cone formation. Electrodes are supplied with a 5 kHz sinusoidal waveform varying voltage from 6 to 16 kVp.

2. Results and discussion

In the pin-to-water DBD discharge a single plasma column is ignited. The discharge filament originates from the pin tip, moving toward the HV plate and spreading on the water surface. This spreading is caused by a charge buildup phenomenon which is under investigation by means of surface potential measurements [1].

In the plane-to-water reactor a multitude of streamers are periodically and randomly ignited in the discharge gap. The randomness of the discharge is due both to the physical behavior observed in the DBDs and to the ripples generated by the streamers injecting on the water surface. These ripples locally decrease the air gap, increasing the electric field and enhancing the discharge ignition.

As shown in Fig.1, in both reactor configurations the capacitive nature of the discharge is clearly visible as the current leads the voltage approximately of a quarter of its period. However, the time behaviours of the current in the two cases is quite different. In the plane-to-water geometry, the discharge current is similar to the one detected for a volumetric DBD operated in air without water.

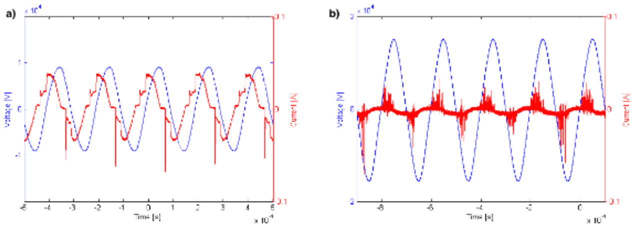

Fig. 1: *Supply voltage and discharge current time behavior for (a) pin-to-water and (b) plane-to-water DBDs.*

In the pin-to-water geometry the discharge current is pretty asymmetric with respect to the positive and negative periods of the applied voltage, because of the charge seeding phenomenon. It was also found that in both configurations the average power increases exponentially with respect to the supply voltage, such as in the air DBDs [2].

Optical emission spectroscopy diagnostics [3] has shown that in both cases a high energy non-equilibrium plasma is formed, as shown in Table 1.

	T_{vib} (K)	T_{rot} (K)
pin-to-water	6000	2300
plane-to-water	2700	900

Tab.1: *Discharge average temperatures for both reactors*

Even though discharges rotational temperatures are higher than the ones registered in air DBDs, water temperature measurements have shown the non-thermal nature of the treatment of both reactors.

Chemical analysis revealed the formation of O_3 and H_2O_2 within the plasma-treated water, necessary to perform an energy-efficient and cost-effective peroxone process.

References

[1] A. Cristofolini, C. A. Borghi and G. Neretti 2013 *Journal of Applied Physics* **113**

[2] G. Neretti, A. Cristofolini and C.A. Borghi, 2014 *Journal of Applied Physics* **115**

[3] G. Dilecce, 2014 *Plasma Sources Science and Technology* **23-1**