Surface DBD in contact with liquids to produce reactive species in liquids and to decontaminate catheters

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Abstract: In this contribution, we report measurements of gaseous and liquid species produced by a surface dielectric barrier discharge with water electrode ignited in two configurations. The antimicrobial effects of such plasma discharge on planktonic *E. coli* in water and on a 48-h biofilm grown on the inner surface of the tubes were studied.

1. Introduction

Surface dielectric barrier discharge (SDBD) systems generate plasma along a dielectric surface but are limited in direct interaction with liquids, restricting the formation of short-lived reactive species in plasma-activated liquids (PAL). To overcome this, we utilize a liquid electrode system that enables SDBD ignition directly from the liquid surface [1]. While plasma-water contact is confined to the dielectric tube's perimeter, the system remains scalable and adaptable, making it suitable for water activation, surface treatment, and medical applications such as catheter decontamination.

2. Experiment

The SDBD discharge was operated in the ambient air at atmospheric pressure. The high-voltage (HV) sine waveform was set to the amplitude of 10 to 20 kV and operated at a frequency of ~31 kHz depending on the experimental conditions. The power to the liquid electrodes was supplied by a high-voltage resonance generator *Lifetech-300W* coupled with a function generator. The electrical characteristics of the discharge were monitored.

Two electrode configurations were investigated: an open-air setup for the treatment of the outer surface of the polymeric tube and an in-tube configuration, where the SDBD discharge was ignited on the inner surface of the tube (Fig. 1). The concentrations of gaseous species were analyzed by the FTIR and UV-vis absorption spectrometers. The treated liquids were analyzed by UV-vis absorption spectroscopy to quantify the aqueous concentrations of ozone (O_3), hydrogen peroxide (H_2O_2), nitrite (NO_2^-), and nitrite (NO_3^-). Antimicrobial effects were tested using a thermostatic plate-counting procedures applied on planktonic *E. coli* in water or on a 48-h biofilm grown on the inner surface of the tubes.

3. Key results

The gaseous plasma products were only O_3, N_2O, and N_2O_5 gas products. The discharge operated primarily in an O_3-dominated mode, with negligible formation of NO, NO_2, HNO_2, and HNO_3 in the gas phase.

The SDBD reactor configuration strongly influences the aqueous species production in PAL. When compared to values reported in the literature, the proposed system exhibits comparable or even superior efficiency in RONS generation, especially in in-tube configuration.

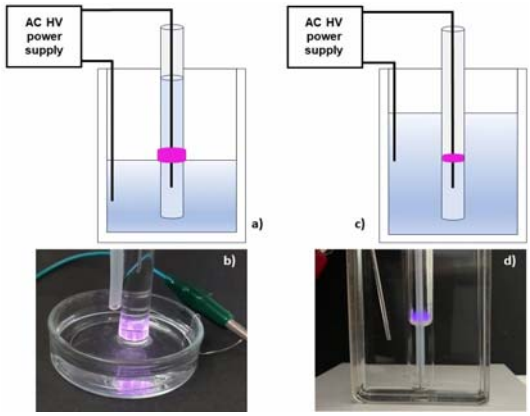

Fig. 1. Schematic arrangement and photo of the Open (a, b) and in-tube (c, d) setups of the surface DBD with liquid.#

The decontamination efficiency tested on both planktonic (in water) and biofilm (on the inner tube surface) forms of *E. coli* resulted in up to 2 log and 6 log reductions in the case of open and in-tube configurations, respectively. Depending on the plasma parameters and the treatment duration, a complete biofilm destruction inside the tube was achieved.

4. Summary

The implementation of SDBD at the gas/liquid/solid interface introduces a novel plasma-based decontamination method for catheters and other medical tubing, and for water treatment. The study demonstrates the potential of SDBD for advanced material processing and sterilization, highlighting its versatility for medical and industrial applications.

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References

[1] O. Galmiz et al., Plasma Sources Sci. Technol. (2025), *under revision*.