

PLASMA JETS AND MULTIJETTS IN IN VITRO EXPERIMENTS: ELECTRO FLUID DYNAMIC AND ENHANCED CELL PERMEABILIZATION

A. Stancampiano¹, T.H. Chung², K. Sklias³, K. Gazeli³, S. Dozias¹, C. Douat¹,
J. Santos Sousa³, P. Escot Bocanegra¹, J.-M. Pouvesle¹, L.M. Mir², E. Robert¹

¹GREMI, CNRS UMR 7344, Université d'Orléans, 45000 Orléans, France

²Université Paris-Saclay, CNRS, Gustave Roussy, VTA, UMR 8203, 94805 Villejuif, France

³Université Paris-Saclay, CNRS, LPGP, 91405 Orsay, France

e-mail: augusto.stancampiano@univ-orleans.fr

Plasma jets are being intensively researched for cancer therapy with encouraging initial clinical outcomes already realised. However, the fine control of plasma jets remains challenging due to the mutual interaction between plasma and target [1]. Even considering perhaps one of the simplest scenarios in a research laboratory, using a plasma jet to treat a 2D culture of cells in a plastic multi-well plate, it is not known in detail how the physical environment of the micro-well may influence the nature of the plasma jet treatment. This study aims to shed light into this topic by investigating how electro fluid dynamic (EFD) flows influence the delivery of the bioactive plasma-generated RONS when a plasma jet is used to treat a conductive biologically-relevant liquid (i.e. PBS) in a standard tissue culture grade 24-well plate [2]. The results show how the formation of complex EFD flows in the liquid induce a non-uniform distribution of the RONS, especially within the first few seconds of treatment (Fig. 1a). Shortly after the ignition of the plasma jet an initial rapid liquid stream can reach the bottom of the well, whereas a stable vortex mixing is observed few seconds later (Fig. 1b). Experimental results indicate that electric charge accumulation on the liquid surface and plasma induced gas swirling could be the causes of the liquid motions. Furthermore, the liquid depth and the voltage polarity were found to be critical parameters in controlling the delivery of the RONS to the bottom of the well. A multijet plasma source was, then, used for the treatment of PBS (pPBS), which was combined with a pulsed electric field (PEF) to permeabilise B16-F10 murine melanoma cells. Compared to PEF alone, the combined treatment with pPBS (applied before and after PEF exposure) can greatly increase the number of permeabilised cells and the uptake of a model non-permeant molecule (Yo-Pro[®]-1) to confirm the permeability of the cell membrane (Fig. 1c). This synergistic effect of plasma treated PBS and PEF could open new opportunities for the application of plasma jets in electrochemotherapy.

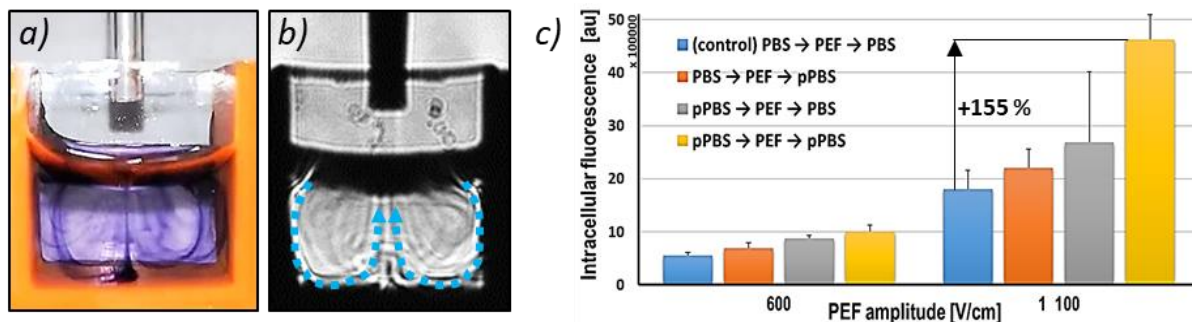


Fig. 1: Plasma jet induced (a) distribution of violet colored RONS-indicator (KI-starch) and (b) vortex mixing in a well containing PBS. (c) Intracellular fluorescence of Yo-Pro-1 in B16-F10 melanoma cells after different combinations of PEF and pPBS treatments

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References

- [1] A Stancampiano, T-H Chung, S Dozias, J-M Pouvesle, L M Mir, and E Robert, *IEEE Trans. Radiat. Plasma Med. Sci.*, 4, 335-342 (2019)
- [2] A Stancampiano, P Escot Bocanegra, S Dozias, J-M Pouvesle, E Robert, *PSST*, 30, 015002 (2021)