Electroporation ability of helium atmospheric pressure plasma jet for normal and cancerous cells

Charalambos Anastassiou[1], Nicolas Charalambous[2], Constantinos Lazarou[1,3] and George E. Georghiou[1,3]

[1] *ENAL Electromagnetics and Novel Applications Lab, Department of Electrical and Computer Engineering, University of Cyprus, Nicosia, 1678, Cyprus*

[2] *Department of Physics, University of Cyprus, Nicosia, 1678, Cyprus*

[3] *FOSS Research Centre for Sustainable Energy, Department of Electrical and Computer Engineering, University of Cyprus, Nicosia, 1678, Cyprus*

INTRODUCTION

In the last two decades, atmospheric pressure plasma jet (APPJ) has gained a lot of attention, due to its low production cost and the wide range of applications that it can be used for such as, plasma medicine, local surface modification, local sterilization etc. In particular, helium APPJ shows very promising results in selectively treating cancerous tissue while leaving the healthy tissue intact. However, the mechanism behind this is not very clear yet and is mainly attributed to the production of radicals which collide with the living tissue and the high electric field generated in the intracellular region [1]. In this study, the transmembrane voltage (TMV) and therefore the ability for electroporation [2] of healthy and diseased cells in the presence of the electric field induced by a helium APPJ is investigated via numerical simulations. Differences in the TMV could explain the ability of APPJ to selectively treat cancerous tissue.

THEORY AND METHODOLOGY

A two dimensional axi-symmetric model that considers a gas dynamic model (GDM) and a plasma fluid model (PFM) was developed [3] for the physical description of a helium plasma jet and its interaction with a dielectric surface that represents the average electrical properties of the tissue. The calculated voltage across the dielectric is subsequently used in a new model that considers the analytical geometry of normal and cancerous cells in order to investigate its effect on the TMV. For the calculations a fixed area of 0.01 x 0.01 $(cm)^2$ where a single cell is placed is used. The voltage is also scaled down accordingly. In order to speed up and simplify the calculations, a 2D model for the cells is used. Cells consist of the cell membrane (10 nm thickness), the cytoplasm, the nucleus and the extracellular fluid. For the normal cells (NC), a circular geometry (10 μm radius) is considered, while for the cancer cells a larger and more irregular geometry is considered. Three different geometries that are becoming progressively more oval are used for the cancerous cells (CC1-3): a circular geometry (CC1, with 20 μm radius), and two elliptical geometries with minor and major axes radii of 10 μm and 20 μm for CC2 and 5 μm and 20 μm for CC3. Furthermore, for the elliptical cells, the induced voltage is applied on the major and minor axis of the ellipse in order to get the entire outcome range. The electrical properties of the cells are taken from [4].

RESULTS AND FIGURES

Figure 1 presents the maximum transmembrane voltage induced on normal and cancerous cell during the interaction with the applied voltage of an atmospheric pressure helium plasma jet. The key observation is that the TMV is higher for the larger cancerous cells (CC1) which could lead to electroporation and therefore treatment of cancerous cells while the normal cells remain unaffected. In addition the move oval cells (CC3) tend to induce lower voltages.

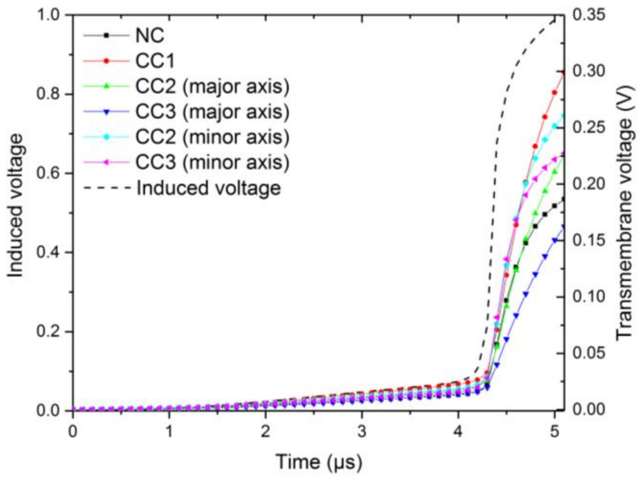

Figure 1: TMV of different cells in helium APPJ.

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