Numerical investigation of electroporation induced by a He and He-O_2 (1000 ppm) plasma jets on healthy and cancerous skin tissues

Constantinos Lazarou[1, 2], Charalambos Anastassiou[1, 2] and George E Georghiou[1, 2]
[1] *ENAL Electromagnetics and Novel Applications Lab, Department of Electrical and Computer Engineering, University of Cyprus, Nicosia, 1678, Cyprus*
[2] *FOSS Research Centre for Sustainable Energy, Department of Electrical and Computer Engineering, University of Cyprus, Nicosia, 1678, Cyprus*

INTRODUCTION

Electroporation is a widely used method in applications such as electrochemotherapy, gene therapy, DNA transfer etc. Electroporation is typically achieved through conductive wires. In this abstract we describe an alternative and non-contact method of achieving electroporation, i.e. through the use of atmospheric pressure plasma jets (APPJs). APPJs have gained tremendous attention in recent years due to low production costs, easy implementation and handling and applications ranging from surface modification, plasma medicine, sterilization etc. In a recent study of Helium APPJ it was found that the addition of oxygen admixtures increased its effectiveness in cancer treatment. This effectiveness was attributed to reactive oxygen and nitrogen species (RONS) produced by the APPJ. However, a recent simulation study from our team showed that the oxygen admixtures increase the strength of the induced electric field (IEF) on the treated surface [1]. We propose that this IEF increases the cell membrane permeability, and thus helps molecules penetrate into the cells. So, it can be inferred that the effectiveness of APPJs lies in the combination of the two effects (high amount of RONS and high IEFs on the treated surface). In this abstract we will study the distribution of IEF from both pure He and He-O_2 APPJ in healthy and cancerous skin. We will show how APPJ can cause electroporation to living tissue in a non-contact method and will show how the addition of oxygen admixtures can increase electroporation.

THEORY AND METHODOLOGY

In this study the interaction of a He and He-O_2 (1000 ppm) APPJ with healthy and cancerous skin tissues placed normal to the jet axis are investigated. The geometry and operational parameters of the plasma jet device and of the simulation model are described in detail in [1]. The healthy and cancerous skin tissue considered here (geometry and electrical characteristics) is similar to those described in [2], [3]. Specifically, the healthy tissue is composed of the stratum corneum, epidermis, dermis, adipose tissue, muscle and subcutaneous tissue. When the tissue is affected by cancer, a tumour is placed in the layer of dermis. The numerical simulations for determining the electric field distribution inside the target tissue are done in two steps. In the first step the plasma model is used to determine the voltage on the surface of the tissue. In the second step that voltage is used to determine the electric field distribution inside the tissue (solving eq. 1 from [2]).

RESULTS AND FIGURES

The induced voltage on the surface of the stratum corneum layer for He-O_2 (1000 ppm) plasma jet is presented in Figure 1. This is the first step from our methodology. In the second step we will determine the field distribution across the various skin layers. We can assume that in the regions where the field is higher than 400 V/cm there will be electroporation.

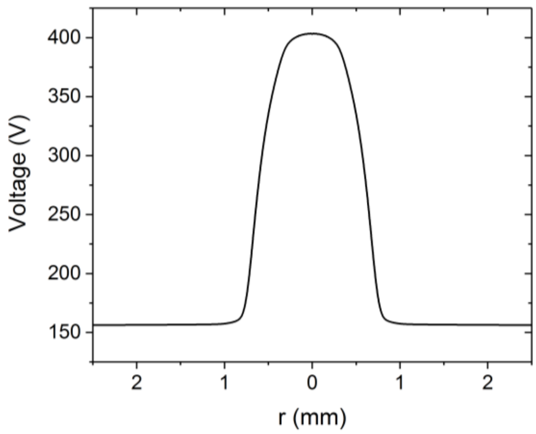

Figure 1: Induced voltage on a healthy skin tissue by a He-O2 (1000 ppm) plasma jet device.

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