Simulation Of Helium Atmospheric Pressure Plasma Jet Using COMSOL Multiphysics®

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Abstract

Atmospheric-pressure plasma jets (APPJ) are devices that generate chemically reactive species and operate at atmospheric pressure and ambient temperature for a wide range of applications. Plasmas jets produce charged particles (electrons and ions), neutral metastable species, radicals, electric fields, and VUV or UV photons. This plasma cocktail not only triggers a variety of cell responses (cell detachment, apoptosis) but is at a temperature that does not damage tissue/skin. APPJs are used routinely in material processing and biomedical applications. Material processing examples include surface modification, etching, and thin film deposition. Plasma medical applications or plasma medicine examples include the killing of cancer cells, wound healing, and sterilisation. Our plasma jet at Queen's University Belfast has shown to be effective in bacteria inactivation.

Our experiment consists of helium gas flowing through an open dielectric tube into air at atmospheric pressure and room temperature. Gas flowing through the quartz tube excited by the pulsed voltage given by the copper electrodes creates the plasma. Adding a small impurity to the noble gas produces the chemically active species. The flow rate of the working gas or the electrical field geometry determines the length of the plasma plume. APPJ can be 1000s K in the tube, but the plasma jet itself can have temperatures of a few 100 K making it ideal for biomedical applications.

We use finite element analysis simulations to benchmark our APPJ. In collaboration with Prof Murakami of Seikei University, we have a working model that is a good match for our experiment. Our model is a fully coupled plasma, turbulent fluid flow, and heat transfer in fluid analysis of our plasma jet created in COMSOL Multiphysics®. The simulation results include the electrical and plasma properties of the jet, including fluid velocity, number density, electron density, reaction rates, plasma potential, and electric fields. COMSOL Multiphysics® enabled us to simulate our experiment's unique power supply which is a pulse decaying sinusoidal waveform. Currently, the model is He only but a complete Air model with reactive species N2 and O2 will be added. We can vary parameters such as gas flow rate, power input, gas admixtures, and electrodes distances and thicknesses in our model to optimise our plasma jet design.

Figures used in the abstract

Figure 1 : Snapshot of electron density in the QUBSEIKEI Atmospheric Pressure Plasma Jet model