The Numerical Simulation Of Apokamp: A Novel Source Of An Atmospheric-Pressure Plasma Jet

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Abstract

In 2016 the group of experimentalists from the Institute of High Current Electronics (Tomsk, Russian Federation) have been discovered a novel phenomenon related to atmospheric plasma jets that was called an "apokamp" (originated from Greek words "off the bend"). This new plasma jet represents a kind of jet developing perpendicular to the bending point of a pulsed-periodic discharge channel initiated between two pin electrodes. The resulting jet is found to be a thin conical plasma structure with a length of 6-8 cm propagating upwards from the initiating discharge channel. One of the most important characteristic features of apokamp - it is not associated with any kind of natural convection or artificially induced gas flows.

In atmospheric air, the apokamp is a unique tool that allows influencing various biological objects with a controlled plasma jet, in which core the active chemical components density is much higher than in classic gas flow induced jets. It is important that apokamp doesn't require any additional gases, e.g. helium. It efficiently delivers reactive oxygen and nitrogen species (RONS) to any biological targets without destroying the delicate cell material with an intensive gas stream, since the latter is simply absent according to the basic principles of apokamp. The RONS list is quite comprehensive, it includes: ozone, hydroxyl radicals, different nitrogen oxides, hydrogen peroxide, nitric and nitrous acids. Depending on the controlled apokamp parameters, effects can range from cell detachment and migration to cell proliferation up to the programmed cell death (apoptosis). In fact, this means that we can attempt using the advanced apokamp plasma chemistry for accelerating plant seed germination, disinfection, wound healing, cancer treatment, non-thermal coagulation, etc. In all of these biomedical applications, the design of apokamp-based devices is extremely simple, easily scalable, and cheap to serial production. It resembles the experimental setup illustrated in accompanying illustrations.

This paper show the numerical simulation of the apokamp plasma jet in the gas of an atmospheric pressure. We used COMSOL Multiphysics® Plasma Module to create the theoretical model of this phenomenon in terms of "two-moment" DC-discharge numerical concept implemented in COMSOL Multiphysics® Plasma Module. This model of a multicomponent discharge plasma describes a self-sustained periodic discharge phenomena in pure oxygen both in the inter-electrode gap and in the surrounding space above the electrodes. To simplify the consideration of a physical situation the 2D-model is used instead of 3D, so the discharge between two plane electrodes with similar to experimental physical conditions has been considered. We also consider a simplified plasma-chemical reactions and species sets for oxygen. Our reduced formulation includes only electrons, neutral molecules O and O2, positive O2+ and negative O2- single charged ions. The reactions number are restricted to four most important: electron impact ionization, impact dissociation, electron attachment and ion-ion recombination. We also used non-uniform initial conditions for quasi-neutral plasma density and temperature distribution in the inter-electrode space to perform the simulations in the pre-conditioned medium.

Figures used in the abstract

Figure 1 : Experimental view of an apokamp phenomena in atmospheric air

Figure 2 : Numerical simulation of the apokamp plasma jet in oxygen (quasineutral plasma distribution)

Figure 3 : Another picture of the apokamp under the atmospheric pressure air