NUMERICAL MODELLING OF DIELECTRIC BARRIER DISCHARGE (DBD) AT ATMOSPHERIC PRESSURE IN A PLANE-TO-GRID REACTOR FOR SOIL REMEDIATION

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ABSTRACT

A dielectric barrier discharge (DBD) is created when a sinusoidal voltage is applied to one of two parallel electrodes wherein one of the two electrodes is covered with a dielectric barrier material. The other electrode is electrically grounded, while the inter-electrode gap is filled with a gas (discharge gap). As the applied voltage increases, the gas is ionized and filamentary microdischarges are generated producing non thermal plasma with high energy electrons, space charge and highly reactive species, such as O, OH, and H radicals, and O_3, H_2O_2 molecules. Among other applications, DBD plasma has been used for the treatment of wastewater and polluted gas, given that all the aforementioned species along with the physical energies involved (e.g. the UV radiation) converge to oxidize the pollutants. During the last few years, DBD plasma has started to be examined as an eco-innovative method of soil remediation.

In the present study, 1D and 2D axisymmetric numerical models are presented, simulating the electrical breakdown in a plane-to-grid DBD reactor used to remediate polluted soils at atmospheric pressure [1]. The simulated domain (Fig. 1) is the space between the two electrodes, including the dielectric (ε_{r1}) covering the high-voltage (HV) electrode (plane disc of diameter 50 mm), the discharge gap (ε_0) and the soil sample (regarded as a dielectric, ε_{r2}) placed on the grounded electrode (grid of diameter 50 mm). The mathematical formulation of both the 1D and 2D axisymmetric numerical models include the application of continuity equation to the charged species coupled with the Poisson equation for the calculation of the electrical potential. At a first approximation, it is assumed that argon (Ar) is the ionized gas since Ar chemistry keeps the number of species and reactions to a minimum.

In this work, the main goal is to elucidate the effect of several external parameters on the generated DBD (e.g. electron and ion density, electron energy, electric field, electron temperature) and electric power consumed during the soil treatment process. The calculation of the electron density is very important as the electrons are at the same time the reactants and energy carriers, initiating the excitation, dissociation,

ionization reactions, etc. In particular, it was found that the voltage, the thickness and permittivity of the dielectric, the thickness and permittivity of the soil and the length of the inter-electrode gap, are all parameters that affect respectably both the characteristics of the generated DBD (Fig. 2) and the electric power consumed.

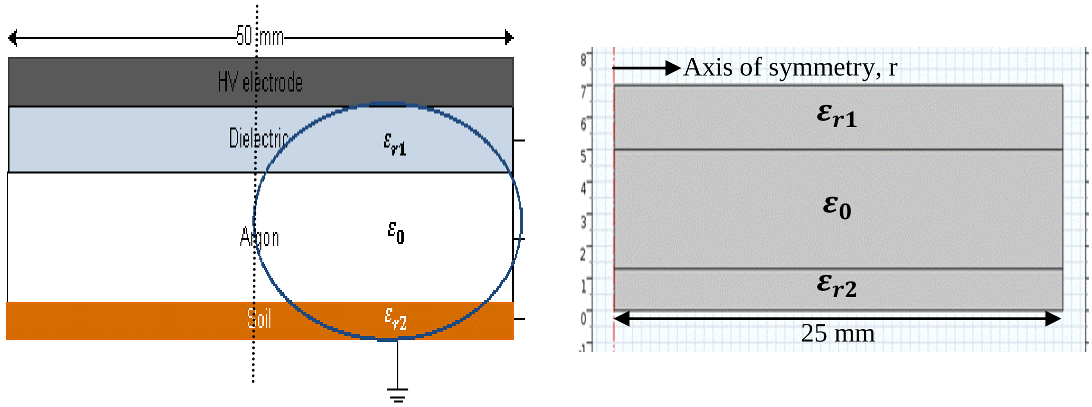

Figure 1. The computational area of the axisymmetric 2D numerical model.

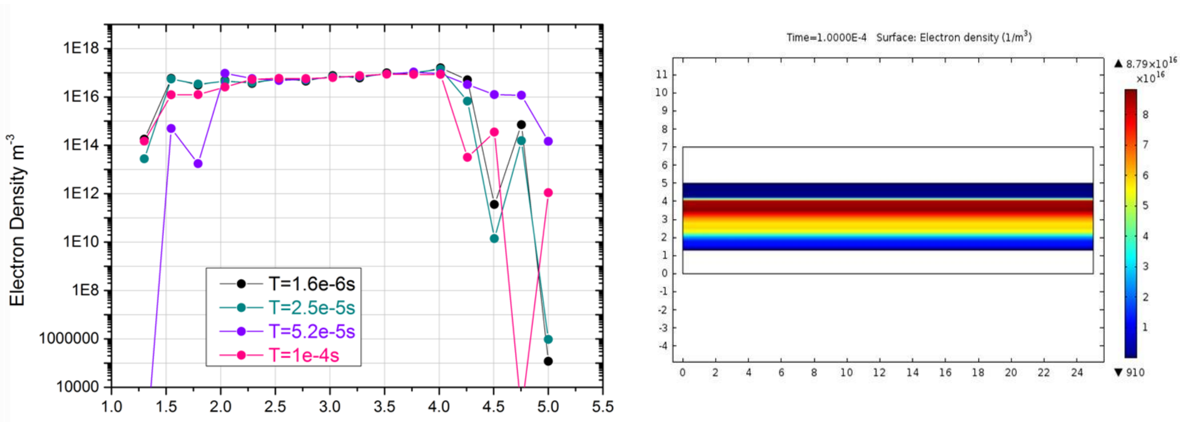

Figure 2. (a) Electron density in the discharge gap at r = 10 mm from the axis of symmetry (applied voltage = 30 kV peak-to-peak, dielectric = 2 mm and ε_{r1} = 2.9, discharge gap = 3.7 mm, soil = 1.3 mm and ε_{r2} = 3.3); (b) 2D graph of electron density (t = 1e-4 s).

References

[1] Aggelopoulos C.A., Svarnas P., Klapa M.I, Tsakiroglou C.D. Dielectric barrier discharge plasma used as a means for the remediation of soils contaminated by non-aqueous phase liquids. Chemical Engineering Journal, accepted (2015).