A COMSOL-based 2D Self-Consistent Microwave Plasma Model

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Abstract

Over the last decades, many studies focused on the description of surface-wave plasmas produced by microwave discharges [1] both from a theoretical and an experimental point of view. These discharges have a wide range of applications, such as gas conversion, plasma medicine, material processing and surface treatment [2] as they offer relative simplicity and low running costs. They can be operated over a wide range of pressure (from few mtorr to several atmospheres), using different frequencies and various geometries [3]. Among these different geometries, the so-called surfaguide discharges offer the possibility to create low-temperatures plasmas coupled with a strong microwave power [3], which is of particular interest for industrial applications.

Recently, microwave discharges have been applied to CO2 conversion and the pressure has been shown to be a key parameter to obtain better energy efficiency, which is crucial in this domain [4].

The goal of this study is to get a better understanding of the effect of the pressure on microwave discharges. The presented model is a self-consistent 2D fluid plasma model of a surfaguide discharge operated over a wide range of pressure conditions: from 10 mbar to atmospheric pressure in pure argon.
COMSOL Multiphysics in used to solve the different equations. The plasma module is used to get the densities of the different species, the mean electron energy and the plasma potential. The equation-based module is used to solve the heat transfer equation (to obtain the gas temperature), the Navier-Stokes equations (to obtain the pressure and the flow velocity) and the Maxwell equations (to obtain the microwave fields). All these equations are solved using the "segregated steps" procedure.

Typical results obtained are shown in the figures attached for a pressure of 1000 Pa.

A reduced set of chemistry for CO2 plasmas is also being developed based on the set of [5]. It will be implemented in the 2D model as a next step.

Reference

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2. Y. M. Aliev et. al., Guided-Wave-Produced Plasmas, Springer, 2000
3. M. Moisan et. al., Plasma sources based on the propagation of electromagnetic surface waves, J. Phys. D: Appl. Phys, 24, 7, 1991
4. A. Fridman, Plasma Chemistry, Cambridge University Press, 2012
5. T. Kozák et. al., Splitting of CO2 by vibrational excitation in non-equilibrium plasmas: a reaction kinetics model, Plasma Sources Sci. Technol., 24, 015024, 2015

Figures used in the abstract

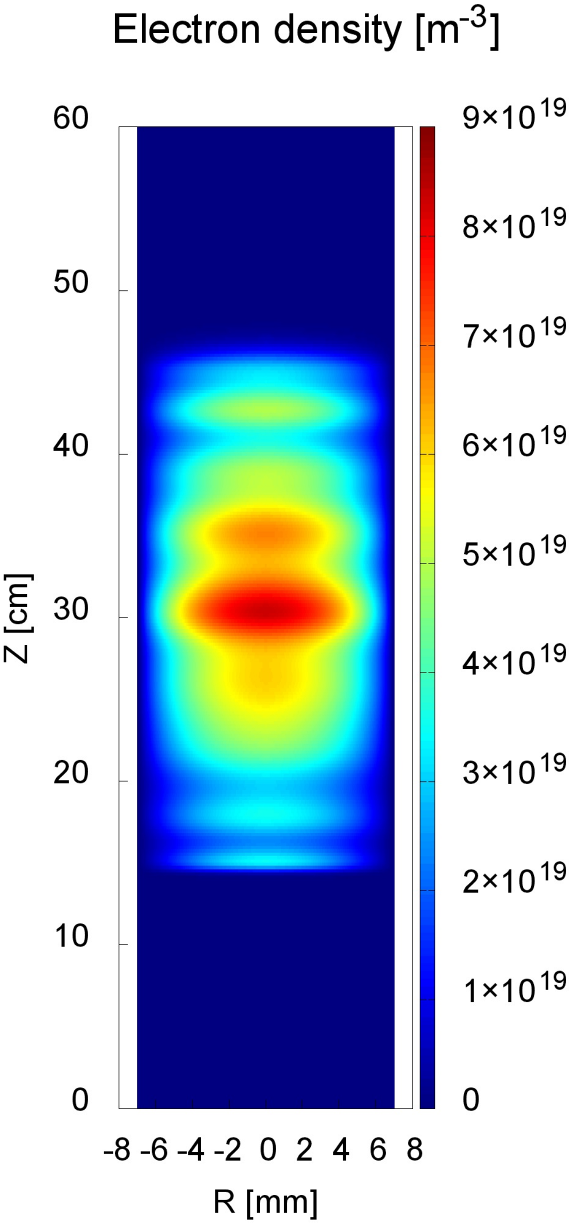

Figure 1: Electron density (m-3)

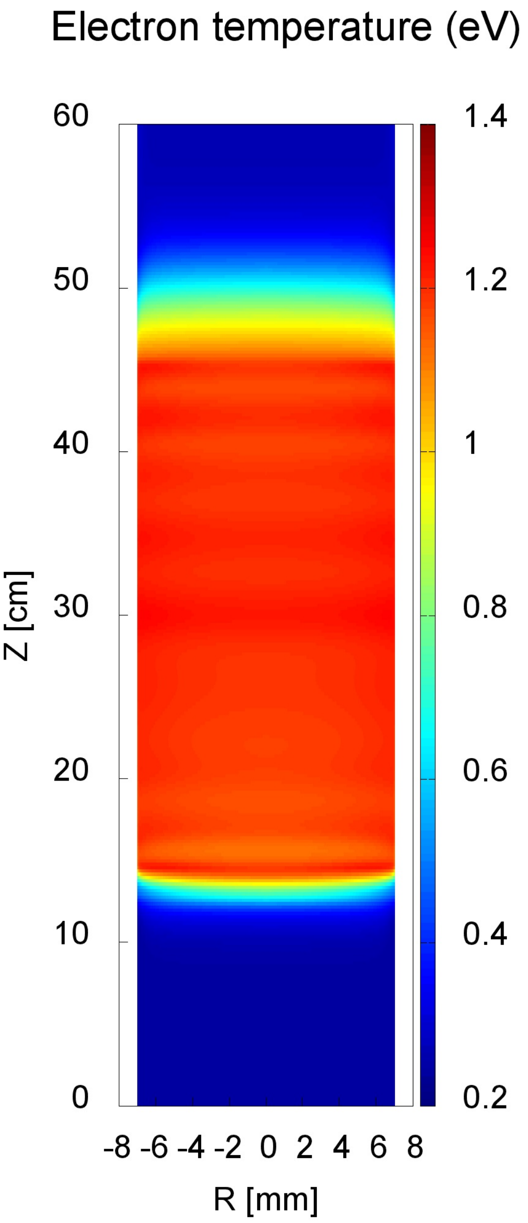

Figure 2: Electron temperature (eV)

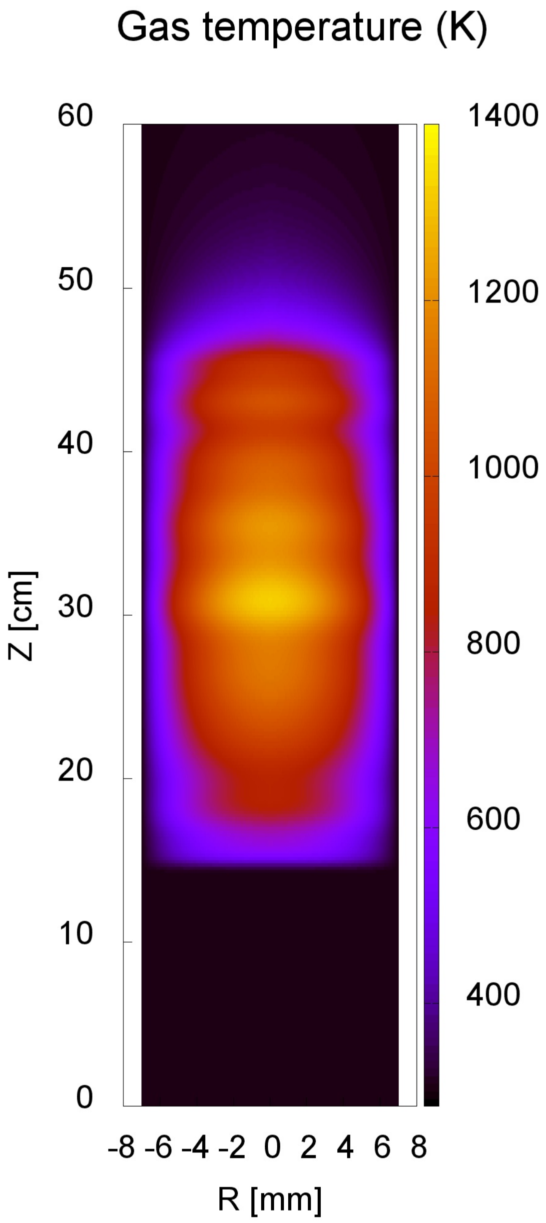

Figure 3: Gas temperature (K)

Figure 4