Numerical Simulation of Resonant Cavity Microwave Plasmas

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Introduction: The resonant cavity microwave plasma has become increasing attractive for microwave electrothermal thrusters as an electric propulsion device as well as material processing under high pressures requiring. In this work, a simulation study of microwave plasma sources with a resonant cavity is performed using COMSOL Multiphysics. Results indicated the variation of electric field induced by the electromagnetic wave during the discharge and the skin effect on the plasma surface. The effect of small amounts of oxygen in Ar/O_2 mixtures on the discharge is examined.

Computational Methods: The research is conducted in a cylindrical resonant cavity, which operates at TM_{011} mode with a frequency of 2.45 GHz. The cavity radius is 50 mm and the cavity height is 175 mm. A 10 mm thick separation plate is placed in the middle of the resonant cavity to separate the regions of plasma and antenna. Pure argon and Ar/0.5-5%O_2 mixtures are used for plasma discharges. The power deposited to the plasma is 100 W. The gas pressures are 40 and 80 torr. The basic equations of the plasma simulations used in this research include a pair of drift–diffusion equations for the electrons, a modified Maxwell–Stefan equation for the ion and neutral species, and a Poisson's equation for the space charge electric field. The plasma species and the chemical reactions are taken from the available literature. The microwave is absorbed over a collisional skin depth: $\delta = (2/(\omega\mu_0\sigma_{\mathrm{dc}}))^{1/2}$, where $\sigma_{\mathrm{dc}} = e^2 n_{\mathrm{s}}/m\nu_{\mathrm{m}}$.

Results: The calculated results for Ar/1%O_2 resonant cavity microwave plasmas at 2.45 GHz at 40 and 80 torr are shown in Figs. 1 and 2. It is shown that the microwave is absorbed near the insulator. The produced negative ions O^- and O_2^-, play an important role.

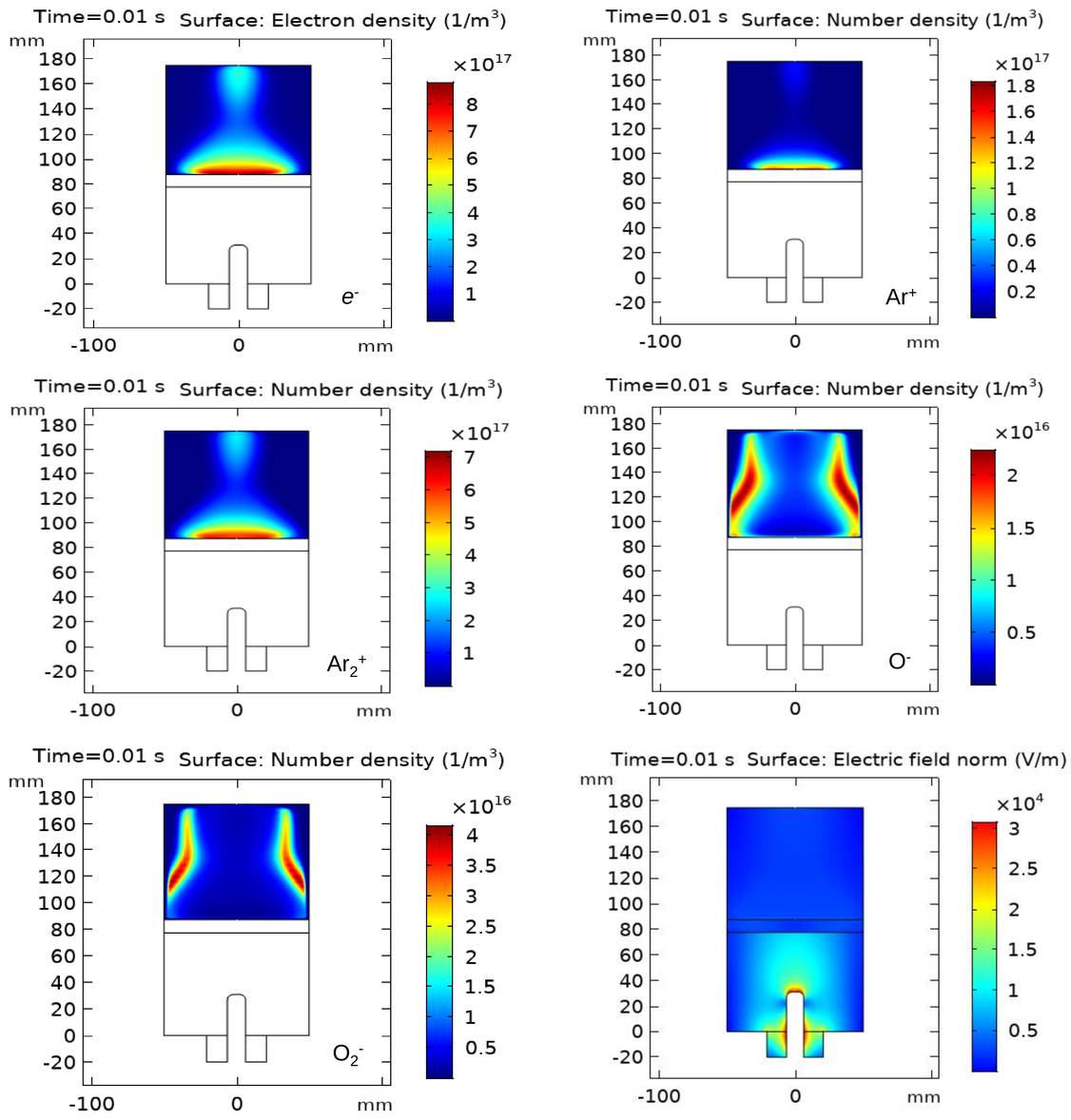

Figure 1. Distributions of plasma species densities and electric field in an Ar/1%O_2 resonant cavity microwave plasma at 40 torr.

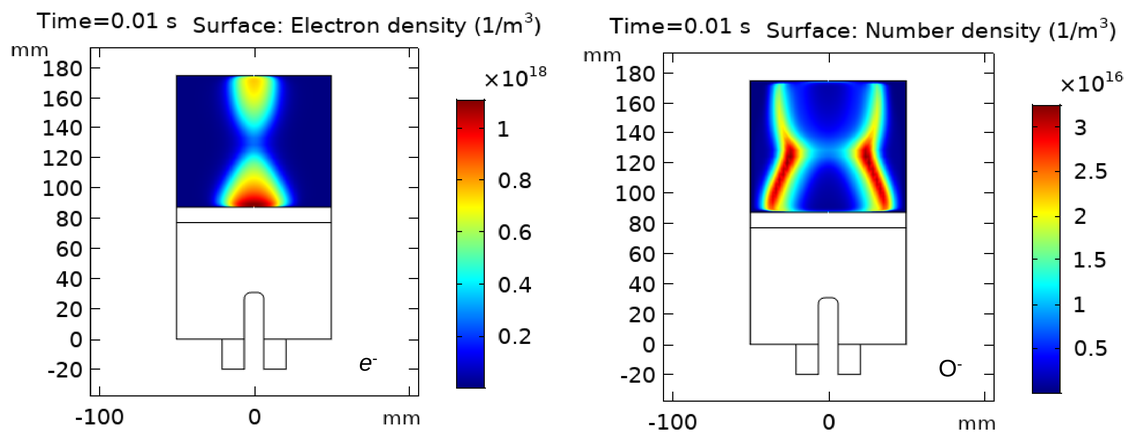

Figure 2. Distributions of the electrons and O^- ions in an Ar/1%O_2 resonant cavity microwave plasma at 80 torr.

Conclusions: Results show the microwave plasma properties of a resonant cavity in pure argon and Ar/O_2 mixtures. The skin effect of microwave at the plasma surface and the effect of the produced negative ions, O^- and O_2^-, especially for the addition of small amounts of oxygen are reported.

References:

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