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Two-dimensional simulations of atmospheric pressure microwave discharge in methane

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Atmospheric pressure microwave discharges find applications mainly in different types of gas processing such as purification of gases, abatement of fluorinated compounds gases, and decontamination of chemical warfare agents. Applying microwave discharges for hydrogen production via hydrocarbons reforming have been reported recently [1,2]. Hydrogen production becomes an important issue currently, because hydrogen is seen by many experts as a promising energy carrier.

A waveguide-based microwave plasma source for hydrogen production via methane decomposition we reported earlier [3]. This plasma source enables stable work with microwave power from 1 kW to 6 kW of absorbed microwave power. It allows for efficient CO_2-free hydrogen production. Basic electric properties of this plasma source including electric field distributions obtained from numerical modeling are presented in [4], however further theoretical investigations are necessary to understand kinetic phenomena in the plasma and improve efficiency of the hydrogen production. Modeling of atmospheric methane plasma has been presented recently [5-7] but the calculations have been performed for other kind of discharges and for the gas temperature lower than that expected in microwave discharges.

In the present contribution, we analyze properties of atmospheric pressure methane discharge generated in the plasma source presented in [3,4]. Systematic simulations have been performed for the discharge with 2.45 GHz frequency for different gas temperatures and reduced electric field that are typical for atmospheric pressure microwave discharges. BOLSIG+ software [8] has been used to determine electron energy distribution functions and the electron temperature as well as transport properties, rate coefficients and total electron collision frequency in the methane plasma.

The results of the studies have been next used for calculating 2D distributions of electromagnetic field, volume density of absorbed microwave power, gas temperature and velocities as well as pressure from a fluid model for assumed electron density distributions. Commercial COMSOL Multiphysics® software [9] has been used for these calculations. A skin effect is observed for the analyses discharge conditions resulting in strong non-uniformity of both the electromagnetic field and density of absorbed microwave power.

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