Numerical study of atmospheric pressure microplasma under a neutral gas dynamics

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Atmospheric pressure glow discharge has a number of advantages based on the characteristics of high plasma density, high process efficiency and environmental compatibility. Under the condition of high pressure and/or large input power, it is usually difficult to sustain a stable non-equilibrium glow discharge (i.e. low temperature plasma) and the glow to arc transition will appear. One of the promising methods for realizing a stable glow discharge is to reduce the size of the plasma to less than ~mm scale aiming at an effective heat transfer to a wall under a large surface/volume ratio. In recent years, microplasmas are gathering much attention for a wide range of applications, such as nano-material synthesis, photonic devices, biomaterial processing, green technology and so on. Deep understanding of the microplasma characteristics including thermal management is of great importance in order to develop the fields of the practical application.

In this study, the two dimensional (2D) property of a microplasma sustained capacitively at radio frequency power (13.56 MHz) is numerically investigated in a cylindrical reactor containing atmospheric pressure of Ar. The characteristic size of the reactor, that is, the effective gap length between a powered electrode and a grounded metallic wall is a few hundred micrometers. In order to evaluate the effect of gas heating, we have newly developed the numerical governing system consisting of a coupled set of models: a neutral gas model including the temperature and flow, a conventional plasma model in gas phase, as well as a heat conduction model in solid phase in the 2D cylindrical coordinates. First, the dependence of a periodic steady state microplasma on gas pressure and input power will be discussed in a steady state gas flow system. Under the condition where high density plasma with the density of $> 10^{12}$ cm^{-3} is sustained at constant high pressure at high power deposition, a local gas heating makes significant influences on the microplasma structure by the change of the local neutral density. Also, the wall temperature will be predicted as one of the key parameters for distinguishing between non-equilibrium plasma and thermal plasma.