Two-dimensional Fluid Simulation of an RF Capacitively Coupled Ar/H2 Discharge

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Abstract

Ar/H2 discharges are frequently used in various industrial applications, such as etching processes, reduction in oxides on surfaces, surface passivation, and film deposition. In these applications, the active species, such as hydrogen atoms and hydrogen ions, are responsible for surface reactions. The degree of dissociation of molecular hydrogen is considered as one of the most important parameters of Ar/H2 plasmas. In order to study the discharge behavior described above, the numerical simulations would be a powerful tool. The properties of Ar/H2 discharges in inductively coupled plasmas (ICPs) have been studied by experimental and global model methods [1]. Radio-frequency (RF) capacitively coupled discharges are among the most powerful and flexible plasma reactors, widely used both in research and in industry [2]. One-dimensional particle-in-cell/Monte Carlo (PIC-MC) model has been developed to study the properties of capacitively coupled plasmas (CCPs) in Ar/H2 [3].

In this work, a two-dimensional fluid model is used to investigate the capacitively coupled discharges in Ar/H2. The study is performed using the Plasma Module of COMSOL Multphysics®. The discharge properties in the Ar/H2 CCP plasmas operating at a RF frequency of 13.56 MHz and a blocking capacitor of 100 nF, are studied. The species taken into account are electrons, molecules (Ar, H2), ions (Ar+, H+, H2+, H3+, ArH+), and neutrals (Ar*, H, H(2p), H(2s)). The calculations include the collisions between excited Ar and H2 (Ar^*+H_2→Ar+H+H), charge exchange collisions between Ar ions and H2 (Ar^++H_2→Ar+H_2^+,Ar^++H_2→H+ArH^+), and other interactions between Ar and H2 (ArH^++H_2→H_3^++Ar,ArH^++e→Ar+H) as well as the chemical reactions occurred in Ar and H2. The densities of all the plasma species for the different H2 fractions are obtained. Figure 1 shows the electron density and electron temperature in an Ar/H2 CCP discharge for H2 fractions of 5% at t = T/4. T is the RF period.

The present work reveals the role of dissociation of molecular hydrogen in Ar/H2 CCP plasmas. The effect of gas composition to discharge properties such as electron density and electron temperature is presented. Results show that the addition of Ar to H2 gas is very useful for easy production of stable plasmas.

Keywords: Ar/H2 CCP plasma, Gas composition, Dissociation rate of H2, COMSOL Multiphysics®

Reference

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Figures used in the abstract

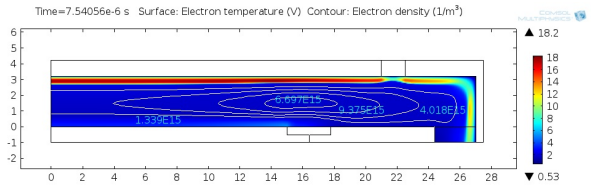

Figure 1: Electron density and electron temperature in an Ar/H2 CCP discharge for H2 fractions of 5% at t = T/4. T is the RF period.