Simulation Study of High Frequency Pulsed DC Discharges in Nitrogen

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Abstract

Pulsed plasmas exhibit improved etching and deposition rates, reduced formation of dust particles, and uniformity of deposition. Pulsed DC technology has led to the design of cost-effective deposition systems and to improved film properties, compared to conventional rf systems. Besides reducing powder formation and allowing more precise control of the generation of reactive species, this technology has allowed the development of more sophisticated equipment with ionization sources and has led to the production of innovative materials [1-3]. Recently, time-resolved measurements of electron density in pulsed DC discharges in nitrogen and argon operating between 0.4~25 kHz have been reported [4]. Although a bi-Maxwellian electron energy distribution was proposed, the plasma properties in these discharges such as electron temperature and densities of the species contributing to metal nitridation were not obtained.

In this work, a two-dimensional finite element model is used to investigate the high frequency pulsed DC discharges in nitrogen. The study is performed using the Plasma Module of COMSOL Multphysics@. The discharge properties in the pulsed plasmas operating at a negative high voltage of -2 kV with high pulse frequencies of 1 and 10 kHz are studied. The gas pressure is 10 Pa. The pulse voltage is connected to the cathode through a series RC circuit comprised of a ballast resistor of 100 □ and a blocking capacitor of 10 nF. The duty cycle ratios (discharge ON time/discharge pulse period) are 25% and 50%. The species taken into account are electrons, ions (N_2^+，N_4^+，N^+), molecules (N_2), excited molecules ($N_2(A^3\Sigma_u^+)$，$N_2(B^3\Pi_g)$，$N_2(B'^3\Sigma_u^-)$，$N_2(a'^1\Sigma_u^-)$，$N_2(a^1\Pi_g)$，$N_2(w^1\Delta_u)$，$N_2(C^3\Pi_u)$), and neutral radicals (N). 34 kinds of chemical reactions are considered.

The present work reveals the role of duty cycle ratios in pulsed DC discharges. The densities of all the plasma species for the different pulse frequencies and duty cycle ratios are obtained. The time-resolved averaged electron density, averaged electron temperature, averaged densities of ions and neutrals are presented. The effect of pulse frequencies on discharge properties such as electron density, electron temperature and so on is examined.

Keywords: Pulsed DC discharge, High frequency, Duty cycle ratio, Nitrogen

References

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Figures used in the abstract

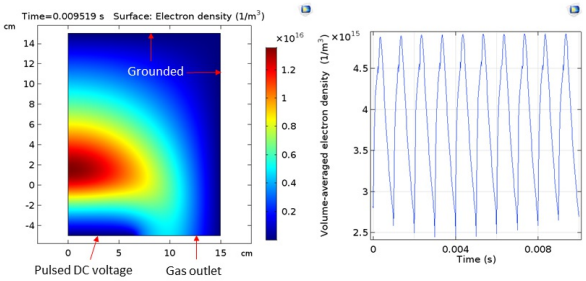

Figure 1: Electron density in the plasma reactor at t = 9.52 ms and time-resolved volume-averaged electron density for the 1 kHz discharge at 10 Pa nitrogen with duty cycle ratio of 25%.