Topic number: 5

Simulation Study of Radio Frequency Capacitively Coupled CF_4 Plasma Discharge – Hollow Cathode Effect

Chia-Yu Chen and Keh-Chyang Leou

Engineering and System Science Department, National Tsing Hua University, Hsinchu, Taiwan, R. O. C

Capacitively coupled plasma (CCP) sources have been widely used for material processing. In this study, carbon tetrafluoride (CF_4) CCP discharges have been investigated by fluid model numerical simulations (CFD-ACE+, ESI Corp.). The simulation model takes into account 12 gaseous species and 41 reactions, and the discharge is generated by a 27 MHz radio frequency power. Simulation results show that, for typical operation conditions the electron density is around 10^{15} - 10^{16} $1/m^3$ while the electron temperature is about 2 - 4 eV in the bulk plasma. The effect of a trench on the grounded electrode is also investigated. For a trench of dimensions smaller than 6 mm x 12 mm, simulation results reveal that there is a significant modification the spatial profile of the plasma density and flux density of important reactive species, as a result of the hollow cathode effect.

1. Introduction

Capacitively coupled plasma (CCP) sources driven by radio frequency power have been widely used for material processing, e.g., dry etching, plasma enhanced chemical vapor deposition (PECVD), and physical and reactive sputtering processes[1]. There have been also a great of interests to take the advantage of the plasma density enhancement by the hollow cathode effect to find tune the CCP discharge characteristics [2, 3]. In this study, numerical simulation analysis based on 2D fluid model (CFD-ACE+, ESI Corp) is carried out to investigate the effect of a trench in the grounded electrode of a 27 MHz CCP discharge. Both Argon (Ar) and Carbon tetrafluoride (CF_4) plasmas have been investigated for two structures, with and without trench.

2. Simulation results

Figure 1 shows the spatial distributions for basic plasma parameters, such as electron density, F and CF_3^+ number densities, for CF_4 CCP discharges of the two different structures. Figure 2 shows radial profiles for electron density at the center of the gap and the F flux incident on the powered electrode surface for the two cases. It is evident that, for the trench of dimension 6 mm x 12 mm, the density profiles of the important species become strongly modified by the presence of the trench, as a result of the hollow cathode effect. It is also interesting to note that the F flux density is enhanced by the hollow cathode effect by a factor ~2 for the entire radial profile, although the enhancement for the electron density occurs only at position beneath the trench. Simulation results also show that the effect of the trench is minimal for trenches of widths less than 4 mm. This is because the trench dimension would need to be greater than two times the sheath width for the hollow cathode enhancement to be effective[4].

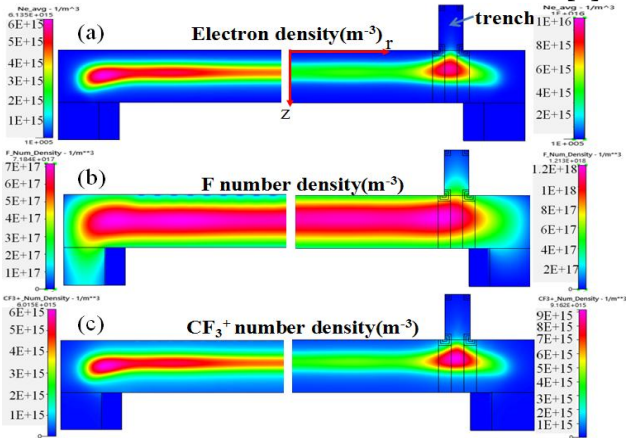

Fig. 1. Simulation results for The spatial profiles of (a) electron density (b) F number density (c) CF_3^+ number density, for the case without (left) and with (right) trench.

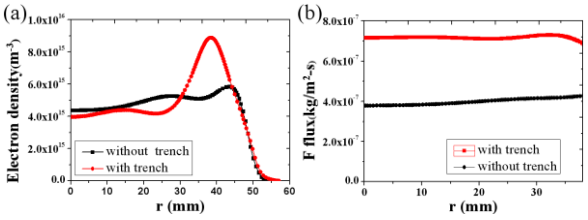

Fig. 2. Simulation results: radial profiles for (a)The electron density at gap center, and (b) F flux density arriving on powered electrode surface.

3. References

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