Two-dimensional Numerical Simulation of a Planar Radio-frequency Atmospheric Pressure Plasma Source

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Abstract

The radio-frequency(RF) plasma sources have shown great potential in various industrial applications such as thin coatings deposition and polymers modification[1,2]. Physics of low pressure RF plasmas has been investigated significantly[3]; however, this kind of plasma source is rarely studied in case of plasma generation under atmospheric pressure conditions. COMSOL Multiphysics® with the Plasma Module provides a powerful tool capable of researching the discharge process to give insight of plasma physics which is difficult to study in the experiment. Two-dimensional capacitively coupled plasma source simulation model is built in this work as presented. The model consists of two 30mm long planar grounded and powered electrodes with a 0.5mm thick dielectric layer(Al_2O_3) placed near the powered electrode. The gap between the dielectric and grounded electrode is fixed at 2.0mm. The discharge is sustained in the helium gas, by imposing a sinusoidal voltage at 13.56MHz on the powered electrode. Due to the limited computational resource, limited set of main plasma initiated reactions is selected from the global model and considered in the present simulation. Besides, the species included in the model are electrons, molecules(He, He metastables), ions(He^+, He_2^+). The mesh convergence is also investigated to increase the mesh density gradually and obtain accurate results. The power evolution is simulated in order to determine the time scale when solution reaching a stable state.

The results show that increasing the mesh density to maximum/minimum element size of 0.045/0.012mm, the maximum electric field magnitude reaches a stable value. This user-controlled mesh is adopted to simulate the model. The power evolution curve demonstrates that the discharge reaches a periodic steady state after 10 RF periods. It is found that electron/ion density (see Figure 1) ranges from 1.88×10^{17} m-3 to 1.92×10^{17} m-3 in the plasma bulk. The electron temperature stayed at 1.85eV in the plasma volume. The ion temperature is observed to increase to 0.65eV in the sheath region nearby the wall. It is found that high energy ion flux can enhance dissociation of the precursor and can be beneficial for different applications e.g. etching the surface of polymer film. This RF atmospheric pressure planar plasma source is considered to be useful for industrial applications.

Reference

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[2] Lieberman M A and Lichtenberg A J 2005 Principles of Plasma Discharges and Materials Processing: Second Edition
[3] Thiry D, Konstantinidis S, Cornil J and Snyders R 2016 Plasma diagnostics for the low-pressure plasma polymerization process: A critical review Thin Solid Films 606 19-44

Figures used in the abstract

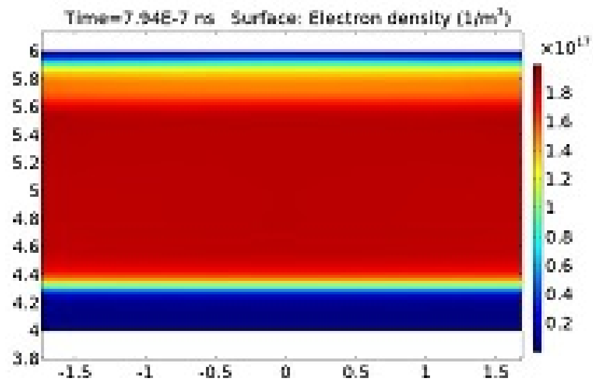

Figure 1: Electron density distributuion at 794ns