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

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Introduction:
The radio-frequency(RF) plasma sources have shown great potential in various industrial applications such as thin coatings deposition and polymers modification[1-2].
An RF atmospheric pressure planar helium discharge is studied through a two-dimensional(2D) COMSOL simulation with a capacitively coupled plasma module. Figure 1 shows the plasma source geometry structure and figure 2 represents the simulation model.

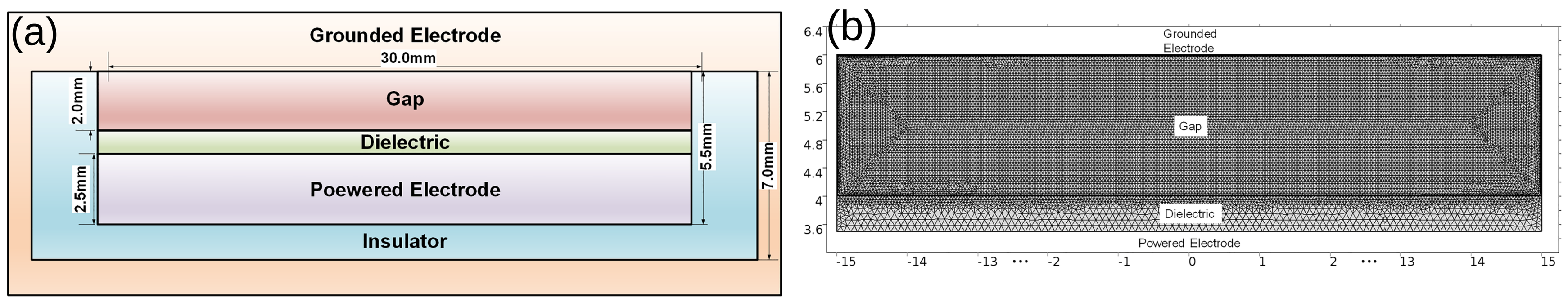

Figure 1. (a) Plasma source geometry and (b) Model in COMSOL

Computational Methods:
Capacitively Coupled Plasma Interface in COMSOL Multiphysics®

❖Electrostatic Field: Poisson equation
❖Electron Transport: continuity equation and drift diffusion equation
❖Heavy Species Transport: Maxwell-Stefan equation
❖Boundary Conditions: metal contact and dielectric contact
❖Initial Conditions:

$$n_{e0} = 10^{17} m^3 \quad \bar{\varepsilon}_0 = 5eV \quad T_g = 273.15K$$
$$P = 1\, atm \quad \varepsilon_r = 10$$

❖Plasma Chemistry: cross section data are mainly calculated from BOLSIG+

Table 1. Reactions included in simulation.

Reaction	Rate(m^3/s)	Types
e+He → e+He	$f(T_e)$	Elastic Collision
e+He → e+Hes	$f(T_e)$	Excitation
e+Hes → e+He	$f(T_e)$	De-excitation
e+He → 2e+He$^+$	$f(T_e)$	Ionization
e+He$^+$ → Hes	$6.76 \times 10^{-19}\, T_e^{-0.5}$	Recombination
Hes+Hes → e+He$_2^+$	$1.4 \times 10^{-31}\, (T_g/300)^{-0.5}$	Associative Ionization

Results:.
Figure 2,3,4 indicate that n_e,T_e,T_i variation follow the RF cycle, while n_i distribution remains almost the same with time. The n_e and n_i range from 1.8×10^{17} m^{-3} to 2.0×10^{17} m^{-3} in the plasma bulk. Figure 4 also suggests that ion temperature increases to 0.9 in the sheath region where ions are accelerated towards the wall.

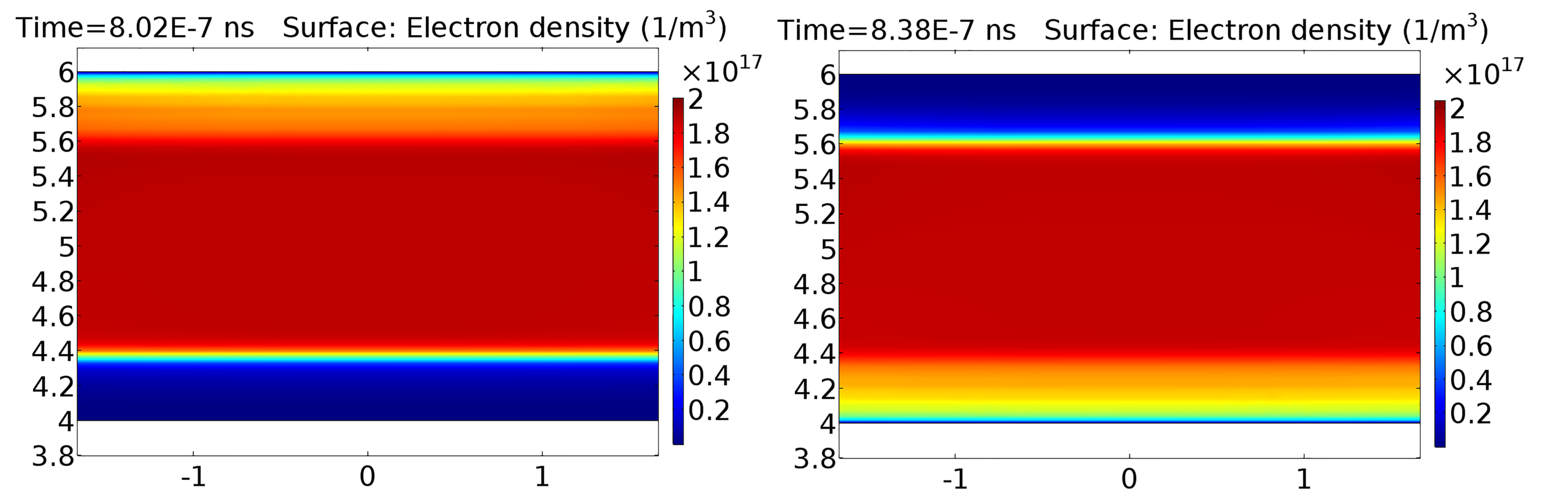

Figure 2. Electron density distribution during half period.

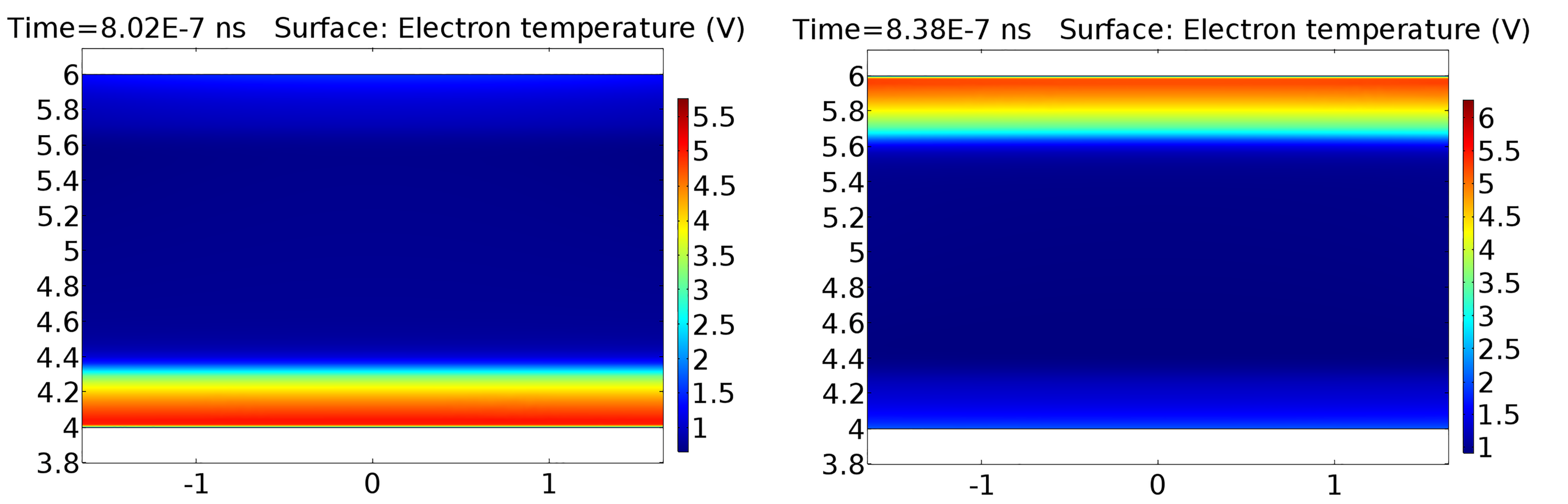

Figure 3. Electron temperature distribution during half period.

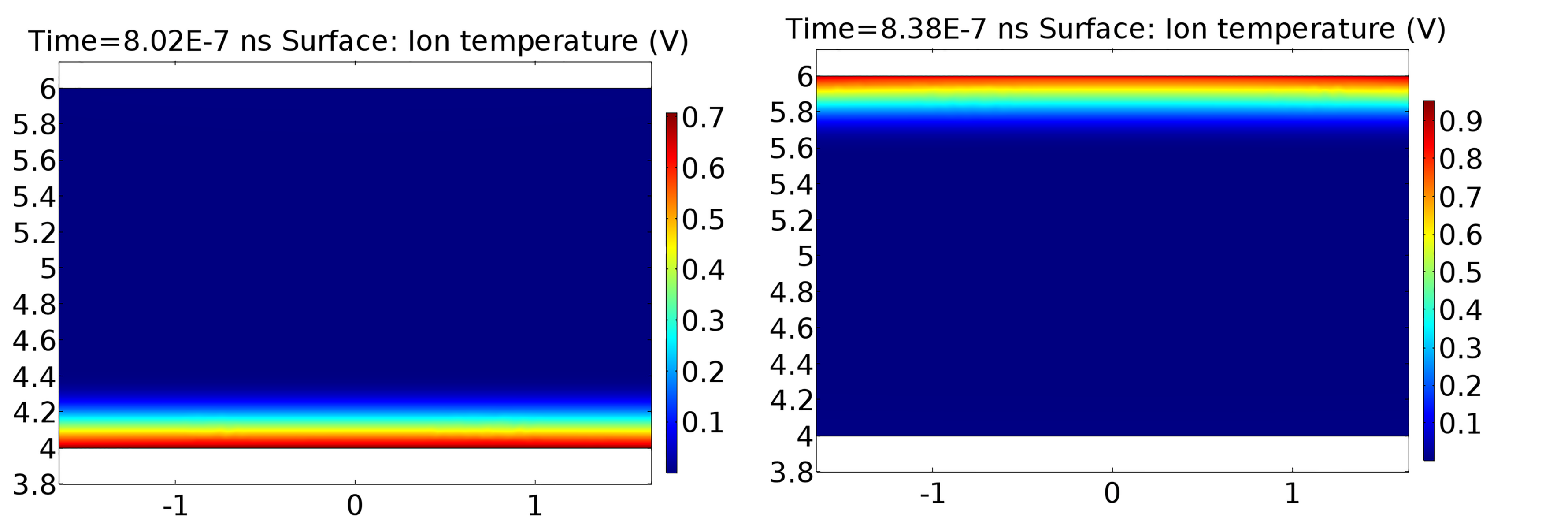

Figure 4. Ion temperature distribution during half period.

Conclusions:
Relatively high ion temperature gives the source potential to be used in coatings and depositions on polymers. Physics of the discharge obtained through COMSOL 2D simulation can provide detailed insights in the discharge operation.

References:
[1] Nair L G, Appl. Surf. Sci. 340 64–71(2015)
[2] Shi J J, Appl. Phys. Lett. 90 111502(2007)