Simulation Study of Microwave Microplasmas based on Microstrip Technology

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Introduction: The generation of stable plasmas can be easily done using microwave generators. The microstrip technology can provide a low-power electrodeless microwave-excited plasma source. In this work, a three-dimensional model is developed based on COMSOL Multiphysics@ to study the plasma source. An effective collision frequency is used to smooth the resonance zone at which the electron density is equal to the critical density. The discharge properties of argon microstrip plasmas at high gas pressures are obtained and analyzed.

Computational Methods: The simulations for a 2.45 GHz microwave-excited argon plasma source applied by an input power of 2 W are carried out. The gas pressures are 50 and 100 Torr and the gas temperature is assumed to be 300 K. The species taken into account are electrons, atomic argon ions (Ar^+), molecular argon ions (Ar_2^+), electronically excited atoms (Ar^*), electronically excited molecules (Ar_2^*), and the background argon atoms (Ar). Dimer species are included because of the relatively high operating pressures.

No.	Reaction	Reaction type
1	$e^- + \mathrm{Ar} \rightarrow e^- + \mathrm{Ar}$	Elastic scattering
2	$e^- + \mathrm{Ar} \rightarrow e^- + \mathrm{Ar}^*$	Excitation
3	$e^- + \mathrm{Ar} \rightarrow 2e^- + \mathrm{Ar}^+$	Ionization
4	$e^- + \mathrm{Ar}^* \rightarrow 2e^- + \mathrm{Ar}^+$	Step-wise Ionization
5	$e^- + \mathrm{Ar}^* \rightarrow e^- + \mathrm{Ar}$	Metastable quenching
6	$e^- + \mathrm{Ar}^+ \rightarrow \mathrm{Ar}^*$	Recombination
7	$2e^- + \mathrm{Ar}^+ \rightarrow \mathrm{Ar}^* + e^-$	Recombination
8	$e^- + \mathrm{Ar}_2^+ \rightarrow \mathrm{Ar}^* + \mathrm{Ar}$	Recombination
9	$2\mathrm{Ar}^* \rightarrow \mathrm{Ar}^+ + \mathrm{Ar} + e^-$	Penning ionization
10	$2\mathrm{Ar}_2^* \rightarrow \mathrm{Ar}_2^+ + 2\mathrm{Ar} + e^-$	Penning ionization
11	$\mathrm{Ar}^* + 2\mathrm{Ar} \rightarrow \mathrm{Ar}_2^* + \mathrm{Ar}$	Excitation transfer
12	$\mathrm{Ar}^+ + 2\mathrm{Ar} \rightarrow \mathrm{Ar}_2^+ + \mathrm{Ar}$	Charge exchange
13	$\mathrm{Ar}_2^* \rightarrow 2\mathrm{Ar}$	De-excitation
14	$e^- + \mathrm{Ar}_2^* \rightarrow 2e^- + \mathrm{Ar}_2^+$	Step-wise Ionization
15	$e^- + \mathrm{Ar}_2^* \rightarrow e^- + 2\mathrm{Ar}$	De-excitation

Table 1. The reactions included in the model.

Results: The representative calculated results are shown in Figs.1-4. The gas pressure is 50 Torr and the input power is 2 W. The number of elements of computational mesh is 122485. The computational time is 35 hours and 24 minutes.

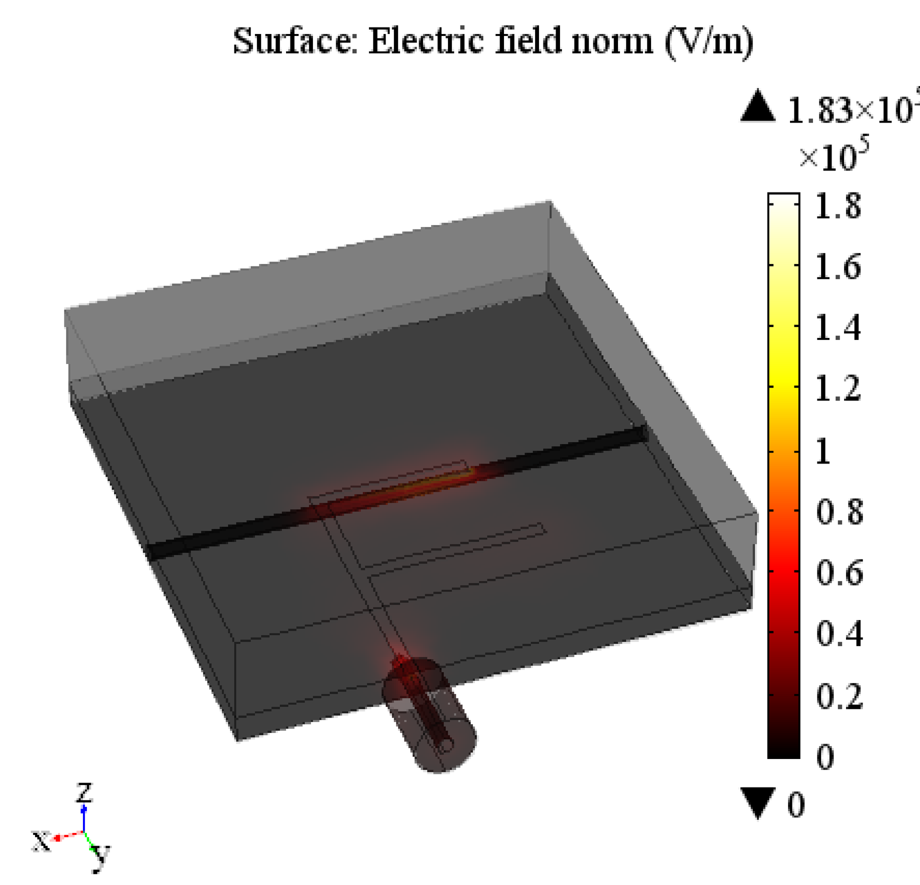

Figure 1. Electric field

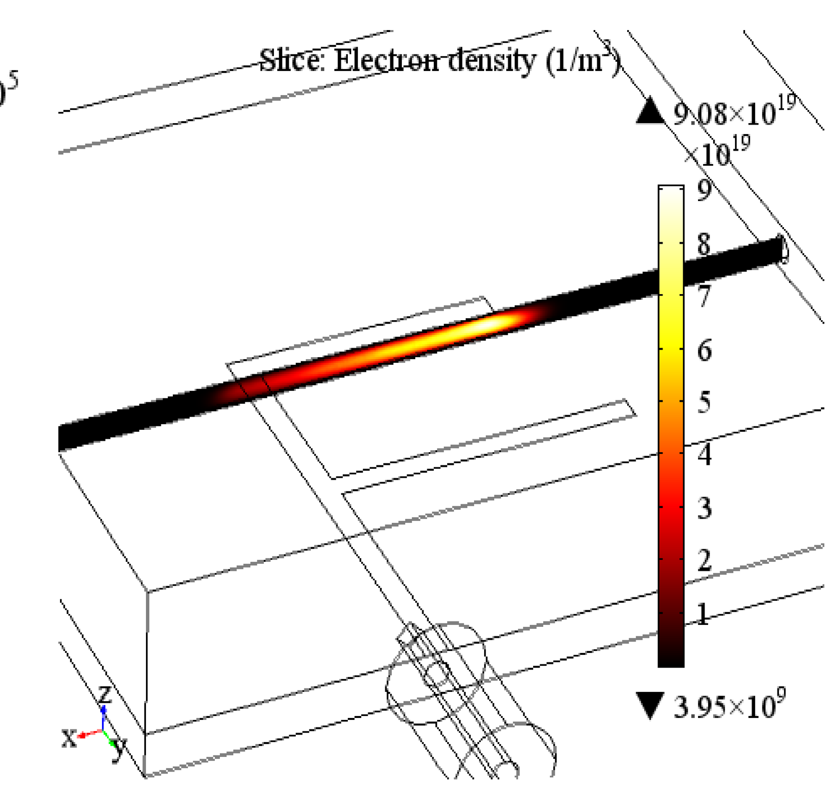

Figure 2. Electron density

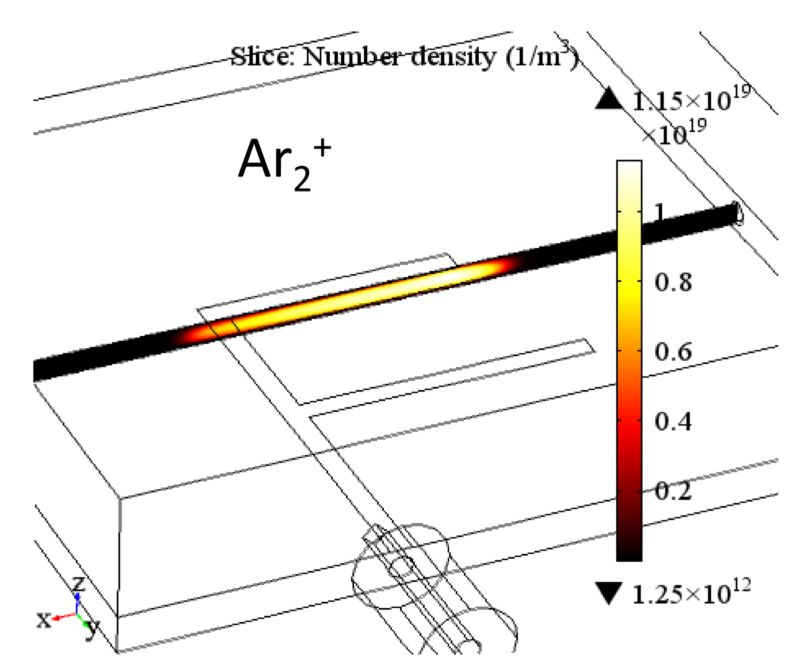

Figure 3. Ar_2^+ density

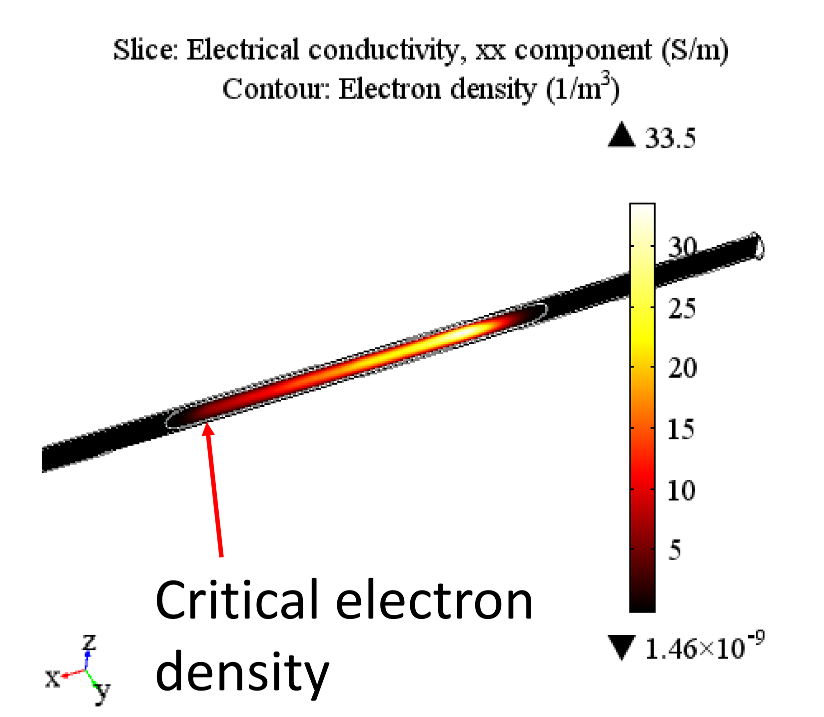

Figure 4. Electrical conductivity

Conclusions: Results show that the micro-wave power is directed to the gas channel of the plasma source. The governed ions are comprised of atomic argon ions (Ar^+) and molecular argon ions (Ar_2^+). A resonance zone in which the electromagnetic wave transits from being propagating to evanescent is formed.

References:

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