SIMULATION OF A CAPACITIVE coupled radio-FREQUENCY DISCHARGE UNDER DYNAMIC VACUUM CONDITIONS [[1]](#footnote-1)\*)

DOI: 10.34854/ICPAF.2023.50.2023.1.1.165

Lazarev E.N., Zheltukhin V.S., Chebakova V.Yu.

Kazan (Volga Region) Federal University, evgenln11401@gmail.com, vzheltukhin@gmail.com, vchebakova@mail.ru

An RF-discharge with a gas flow in the pressure range of 13.3-133 Pa (i.e. *dynamic vacuum*) is effectively used for processing various materials in order to improve the functional and operational properties of products [1]. To optimize the processing modes, it is necessary to understand the processes occurring in the discharge. So, a mathematical model of high-frequency capacitive (HF) discharge is developed for the following discharge burning conditions: field frequency 13.56 MHz, discharge power from 0.5 up to 5 kW, gas flow rate up to 0.2 g/s [1].

The model is a non-linear system of equations that includes initial-boundary problems for the balance equations for the concentration of electrons, ions, neutral and metastable atoms, energy conservation of the electron gas, boundary value problems for the energy conservation equation of the carrier gas and the Poisson equation for the electric field potential.

The balance equations for electron and ion gases, metastable atoms and atoms in the neutral state consider the processes of direct ionization, recombination, stepwise and penning ionization, processes of excitation and quenching of metastable states. The boundary conditions for the balance equations for the electron and ion gases, as well as for metastable atoms, are formulated in the conventional form [2, 3]. The boundary conditions for the balance equation of neutral atoms are formulated based on the ideal gas equation. The boundary conditions for the potential take into account the sinusoidal voltage change at the loaded electrode.

For the numerical implementation of the model, an implicit finite-difference scheme on a uniform grid was used. The Scharfetter-Gummel algorithm [4, 5] was used to calculate the diffusion-drift flux of charged particles.

The results of numerical simulation showed that gas heating significantly affects the distribution and fraction of charged and excited particles in the discharge gap.

The study was granted by the Russian Science Foundation (project no. 19-71-10055).

References

1. Abdullin I.Sh., Zheltukhin V.S., Kashapov N.F. (2000) Radio-frequency plasma-jet processing of materials at reduced pressures. Theory and practice of application. Kazan: Kazan Univ. Publ. House. [Vysokochastotnaya plazmenno-struynaya obrabotka materialov pri ponizhennykh davleniyakh. Teoriya i praktika primeneniya. Kazan': Izd-vo Kazanskogo un-ta – in Russian].
2. Raizer Yu.P., Shneider M.N., Yatsenko N.A. (1995) Radio-frequency capacitive discharge: Physics. Experiment technique. Applications. M.: MIPT Publishing House [Vysokochastotnyy yemkostnyy razryad: Fizika. Tekhnika eksperimenta. Prilozheniya. M.: Izdatel'stvo MFTI – in Russian].
3. Chebakova V.Yu. (2015) // Transact. Kazan Univ. Ser. Phys.-Math. [Uch. zapiski Kazan. un-ta. Ser. fiz.-mat. Nauki – in Russian] 157 (2) 126–140.
4. Scharfetter D.L., Gummel H.K. (1969) // IEEE Trans. Electron Devices, 16 (1) 64–77.
5. Zheltukhin V.S., Fadeeva M.S., Chebakov V.Yu. (2017) // Transact. Kazan Univ. Ser. Phys.-Math. [Uch. zapiski Kazan. un-ta. Ser. fiz.-mat. Nauki – in Russian] 159 (4) 444–457.
1. \*) [abstracts of this report in Russian](http://www.fpl.gpi.ru/Zvenigorod/L/Lt/ru/FS-Zheltukhin.docx) [↑](#footnote-ref-1)