4th Asia-Pacific Conference on Plasma Physics, 26-31Oct, 2020, Remote e-conference

Pulsed plasma simulations using the global model for inductively coupled plasma sources

D. C. Kwon[1] and H. C. Lee[2]
[1] Plasma Technology Research Center, National Fusion Research Institute
[2] Advanced Instrumentation Institute, Korea Research Institute of Standard and Science
e-mail (speaker): dckwon@nfri.re.kr

The volume-averaged global plasma model has been widely used to analyze the characteristics of plasma, although the spatial variation of plasma parameters cannot be obtained from it. It has also been used to obtain temporal plasma parameters for pulsed plasma sources. In this work, we analyzed the effect of an edge-to-center density ratio (*h* factor) and an electron heating model on plasma parameters in pulsed plasma simulations using the global model for Ar discharges.

For electropositive plasmas, Godyak and Maximov derived the edge-to-center ion density ratios h_L and h_R by solving the nonlinear low-pressure diffusion equation for the boundary conditions $u_i = 0$ at the plasma center and $u_i = u_B$ at the sheath edge [1]. However, it has not been sufficiently investigated whether the *h* factor derived by assuming the steady state can be applied to pulse simulations using the global model. Because the uniformity of the plasma can change during the pulse period, the *h* factor can change, too. Therefore, in order to analyze the time-varying effect of the *h* factor, we assumed that the *h* factor varies between $h_{\min}$ and $h_{\max}$ during the pulse period (transient *h* factor), as shown in Fig. 1 [2].

In order to analyze the effect of the absorbed power on the plasma parameters, we used Yoon's analytic electron heating model, which includes a nonlocal electron heating mechanism [3]. Yoon *et al*. derived the electromagnetic fields inside the chamber using the mode excitation method. From these fields, the total reactor impedance was obtained as a function of various plasma and chamber parameters. When the stray resistance of the chamber is ignored, the real part of the reactor impedance equals the plasma resistance. Therefore, the absorbed power is given by

$$P_{abs} = \begin{cases} \dfrac{R^{(p)}}{R^{(p)} + R^{(c)}} P_{rf}, & (0 \le t < \alpha t) \\ 0, & (\alpha t \le t < \tau) \end{cases}$$

where $R^{(p)}$ is the plasma resistance (*i.e.*, the real part of the reactor impedance), $R^{(c)}$ is the antenna resistance, P_{rf} is the power supplied at the powered antenna, α is the duty ratio, and τ is the period.

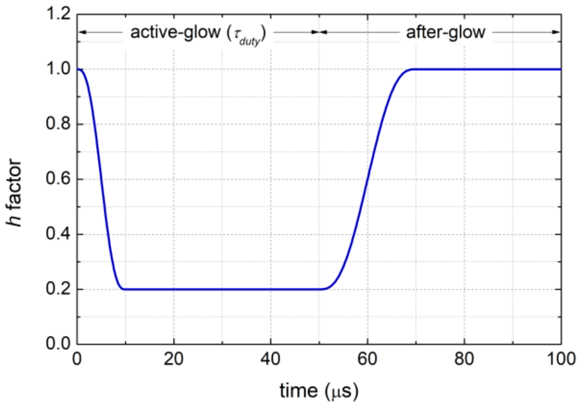

Fig. 1. An example of the *h* factor when the pulse-repetition frequency is 10 kHz.

Figure 2 shows the electron temperature profiles when the electron heating and transient *h* factor are considered. It is observed that the electron temperature increased gradually initially and then increased rapidly in the early active-glow stage of the pulse. This behavior is closely related to plasma resistance, which is also observed experimentally. The self-consistent heating model increases the realism of the simulation by preventing the electron temperature from reaching non-physical values. Moreover, the *h* factor significantly affects the temporal profile of the electron temperature.

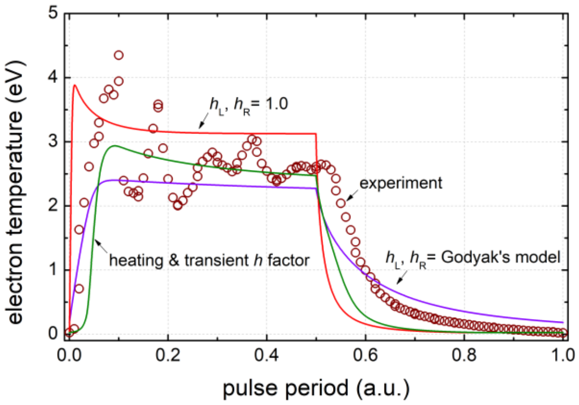

Fig. 2. Electron temperature profiles at 10 kHz when the electron heating and transient *h* factor are considered.

References
[1] V. A. Godyak, Soviet Radio Frequency Discharge Research (Delphic Associates, Falls Church, VA, 1988).
[2]https://abaqus-docs.mit.edu/2017/English/SIMACAEPRCRefMap/simaprc-c-amplitude.htm
[3] N. S. Yoon, S. M. Hwang, and D. I. Choi, Phys. Rev. E 55, 7536 (1997).