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# Equivalent circuit modeling for electrical parameter diagnostic of a pulse-modulated RF capacitively coupled plasma

Xian Zhang[1], Xiao-Kun Wang[2], and Yong-Xin Liu[1]

[1]Key Laboratory of Materials Modification by Laser, Ion, and Electron Beams (Ministry of Education), School of Physics, Dalian University of Technology, Dalian 116024, People's Republic of China

[2]Chair of Applied Electrodynamics and Plasma Technology, Ruhr-University Bochum, 44780 Bochum, Germany

e-mail (speaker): yxliu129@dlut.edu.cn

Very high frequency (VHF) capacitively coupled plasma (CCP) sources are widely utilized in etching processes during chip manufacturing [1]. However, due to the presence of stray impedances (including capacitance, inductance, and resistance) within the vacuum chamber excited by a VHF source, discrepancy of electrical parameters arises between measurement point and electrode surface inside the chamber. At lower driving frequencies (e.g., f = 13.56 MHz), stray impedance is primarily attributed to capacitance, while stray inductance also plays a key role at higher driving frequencies (e.g., f ≥ 27.12 MHz). In order to obtain more accurate inter-electrode voltage, $V_{rf}$, plasma current, $I_{rf}$, plasma power absorption, $P_{rf}$, and phase, $\varphi_{vi}$, it is imperative to establish an equivalent lumped circuit model for the reactor. In this study, two equivalent lumped-circuit models, i.e. the C model and the RLC model (see figure 1), are compared. The element values of the two equivalent circuits are determined by fitting the impedance spectrum over 1 MHz ~100 MHz.

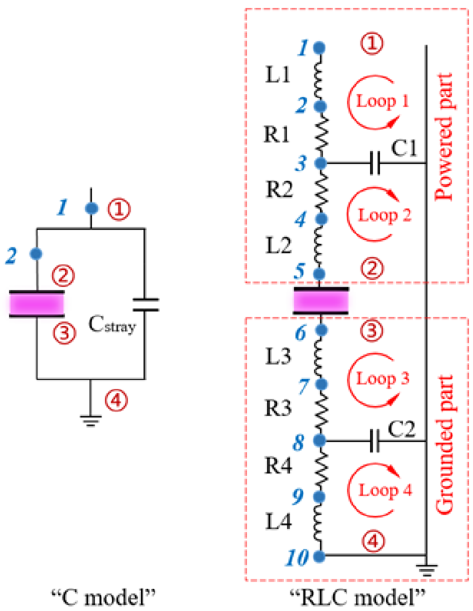


Figure 1. Two external circuit models: C model and RLC model

With the lumped circuit model, the temporal evolution of the electrical parameters of a pulse-modulated VHF CCP are determined. The results of the RLC model suggests that the presence of equivalent inductance of the power feeding rod leads to a large deviation of the inter-electrode voltage drop from the measured value outside the reactor, and this deviation becomes significant with increasing driving frequency (see figure 2). So, at f ≥ 27.12 MHz, stray inductance of the powered rod should be considered for a more accurate measurement. Meanwhile, the equivalent resistance at the end of the powered rod results in substantial power dissipation, primarily due to large flowing current passing through this region. In addition, the electrical parameters under varying driving voltages are calculated using the RLC model, and the temporal evolution of plasma optical emission intensity (OEI) at the onset of each pulse is compared with $P_{rf}$, indicating a consistent dynamic behavior between these parameters.

References
[1] M A Sobolewski, Journal of Vacuum Science & Technology A, 1992. 10, 3550-3562.

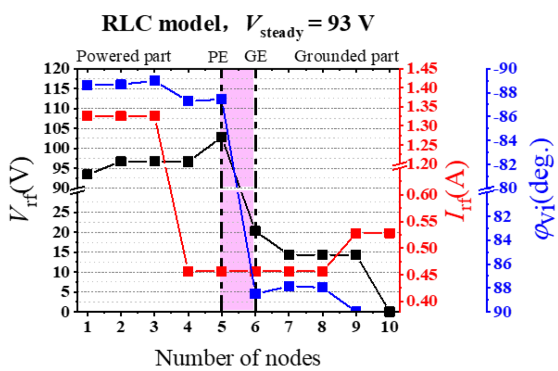


Figure 2. voltage amplitude ($V_{rf}$), current amplitude ($I_{rf}$), and V-I phase ($\varphi_{vi}$) obtained from RLC model at different nodes marked in figure 1 during the steady-state period. PE: powered electrode; GE: grounded electrode.