Complex transients of input power and electron density in pulsed inductively coupled discharges

Xiang-Yun Lv[1], Fei Gao[2], Quan-Zhi Zhang[3] and You-Nian Wang[4]

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

e-mail (speaker):LXY2036@mail.dlut.edu.cn

Time-dependent studies of pulsed inductively coupled Ar and Ar/CF_4 discharges are presented in this work. By using a time-resolved power diagnosis system, i.e., a Langmuir probe and a Hairpin probe, the temporal evolutions of input power and electron density are measured.

As show in Fig. 1, in the initial pulse stage, the input power exhibits two peaks, which are related to the properties of the source and the plasma, respectively. In addition, an overshoot of the electron density is observed in the initial pulse stage at high powers (500–800 W) and low pressures (1–10 mTorr), and the overshoot becomes weaker by increasing pressure (10–80 mTorr) or decreasing input power (200–500 W). This can be explained by the dependence of the power transfer efficiency on pressure and input power, as well as the balance between the electron production and loss rates[1,2]. When the power is turned off, the electron density and the input power exhibit a peak at the initial afterglow period, due to the release of charges from capacitors and inductors in the radio frequency power source.

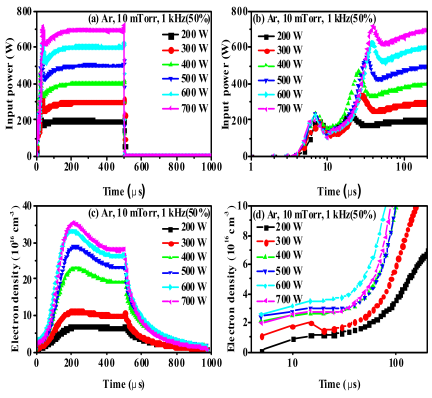

FIG. 1. Temporal evolutions of the input power and the electron density for different powers at 10 mTorr in Ar discharges, with a pulse frequency of 1 kHz and 50% duty cycle, (a) the input power for the whole pulse period, (b) the input power until 200 μs in the initial pulse stage, (c) the electron density for the whole pulse period, and (d) the electron density until 200 μs in the initial pulse stage.

We can see in Fig. 2, the plasma responds to the changes in the input power more quickly in Ar/CF_4 discharges than in Ar discharges, so it takes a shorter time to reach the ionization equilibrium. This may be caused by more ionization channels, larger ionization cross section, and lower ionization thresholds in Ar/CF_4 plasmas[3,4].

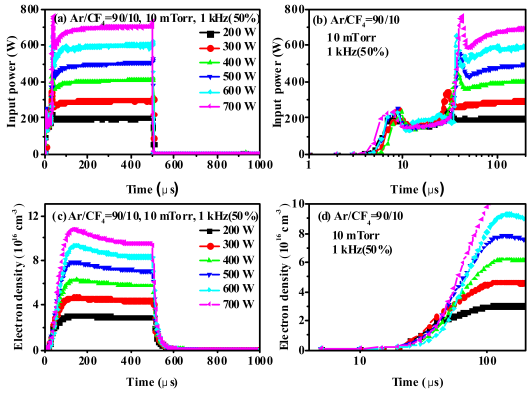

FIG. 2. Temporal evolutions of the input power and the electron density for different powers at 10 mTorr in Ar/CF_4 discharges, with a pulse frequency of 1 kHz and 50% duty cycle, (a) the input power for the whole pulse period, (b) the input power until 200 μs in the initial pulse stage, (c) the electron density for the whole pulse period, and (d) the electron density until 200 μs in the initial pulse stage.

This work was supported by the National Magnetic Confifinement Fusion Science Program, China (Grant No. 2015GB114000) and the National Natural Science Foundation of China (NNSFC) (Grant Nos. 11675039 and 11875101).

References

[1] V. A. Godyak, R. B. Piejak, and B. M. Alexandrovich, J. Appl. Phys. 85, 703 (1999).
[2] V. A. Godyak, Plasma Sources Sci. Technol. 20, 025004 (2011).
[3]P. Ho, J. E. Johannes, and J. Buss, J. Vac. Sci. Technol. A 19, 2344 (2001).
[4]S. X. Zhao, F. Gao, Y. N. Wang, and A. Bogaerts, Plasma Sources Sci. Technol. 21, 025008 (2012).