Modulation of electron energy distribution functions and plasma parameters in a dual-frequency cylindrical inductively coupled plasma source

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Dual-frequency(DF) inductively coupled plasma (ICP) source in etching and deposition processes of semiconductor industry has attracted much attention, since it can acquire a higher etching or deposition rate, better uniformity, and independent control of ion energy and ion flux. In this paper,a new DF cylindrical ICP source which operated with DF (high-frequency 13.56 MHz and low-frequency 2 MHz) and dual antennas (a 2-turn high-frequency antenna and a 6-turn low-frequency antenna) is designed with promising properties. The high-frequency antenna and low-frequency antenna are interwound to ensure the overlap of high-frequency and low-frequency discharge area. Then the effects on electron energy distribution function (EEDF) and plasma parameters (i.e., plasma density n_e, electron temperature T_e, plasma floating potential V_f and plasma potential V_p) in the following cases are investigated: (1) fixed high-frequency power of 500 W and low-frequency power varying from 300 W to 900 W, (2) fixed low-frequency power of 500 W and high-frequency power varying from 300 W to 900 W. It is found that increasing high-frequency power enhances the population of high-energy electrons, while increasing low-frequency power increases the population of low-energy electrons. This result can be explainedby the different electron heating mechanisms, i.e., ohmic heating for the low-frequency discharge and collision-less heating for the high-frequency discharge at an argon gas pressure of 15 mTorr.

Moreover, the different influences of high-frequency power on n_e, T_e, V_f, V_p at fixed low-frequency power of 500 W and that of low-frequency power on n_e, T_e, V_f, V_p at fixed high-frequency power 500 W are compared. It is found that although n_e increases with both high-frequency and low-frequency power, it increases more significantly with the change of high-frequency power. This indicates that n_e is mainly determined by the high-frequency power and slightly influenced by the low-frequency power. Furthermore, the T_e, V_f and V_p decrease with increasing low-frequency power at fixed high-frequency power of 500 W, which is contrary to the trend of T_e, V_f and V_p with increasing high-frequency power at the same low-frequency power of 500 W.

In addition, the modulation of electron energy distribution functions and plasma parameters at different gas pressures which corresponds to different electron heating mechanisms, e.g. collision-less heating for both high-frequency and low-frequency, collision heating for both high-frequency and low-frequency, and collision-less heating for high-frequency and collision heating for low-frequency are also compared and discussed.

This work is supported by theNational Natural Science Foundation of China (Grant No.11475038).