Improvement of the radial uniformity in pulsed inductively coupled plasmas

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Inductively coupled plasma (ICP) has been widely used in etching processes on account of its superiority, i.e., simple structure and high plasma density at low pressure. With the increasing of the wafer size and decreasing of the characteristic line-width in industry, ICP source, which can produce large-area uniform plasma, is critically required to enhance productivity and reduce manufacturing cost[1]. Initially, pulse modulated radio-frequency (RF) inductively coupled discharge was proposed to better control of plasma parameters. Recent researches have shown that the plasma uniformity can also be controlled by pulse modulation[2].

In this work, a two-dimensional fluid model coupled with an electromagnetic field module, is used to systematically investigate the radial uniformity in pulsed inductively coupled plasmas, under different discharge parameters, such as pulse duty cycle and coil current.

The radial distributions of the electron density at the chamber center and the ion flux at the substrate have been shown in Fig. 1. Continuous sinusoidal currents are applied to the inner coils, and the outer coils are pulsed, with the duty cycle of 10%, 30%, 50%, 70% and 90% respectively. The current is fixed at 2.5 A, and the frequency is 13.56 MHz. As shown in Fig. 1, when the pulse duty cycle is 50%, the best radial uniformity of the electron density and ion flux is observed. Moreover, the maxima of the electron density and ion flux move from the center to the radial edge as the pulse duty cycle increases from 30% to 90%. This is because the glow period gets longer as the pulse duty cycle increases, thus more electrons are accumulated at the radial edge of the substrate[3].

Since the power deposition induced by the coils determines the plasma generation, the plasma uniformity can also be modulated by coil current[4]. By fixing the pulse duty cycle at 50% and the coil frequency at 13.56 MHz, the influence of the outer coil current on the plasma uniformity is shown in Fig. 2. With the increase of the outer coil current from 2.1 A to 2.9 A, both the electron density at chamber center and the ion flux at the substrate gradually increase at the radial edge, and the best plasma uniformity is obtained at 2.5 A.

References

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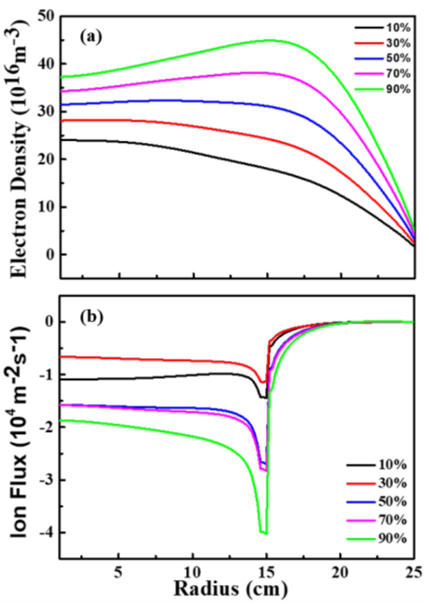

Fig. 1. Radial distributions of the (a) electron density at the chamber center, and (b) ion flux at the substrate, for different pulse duty cycles.

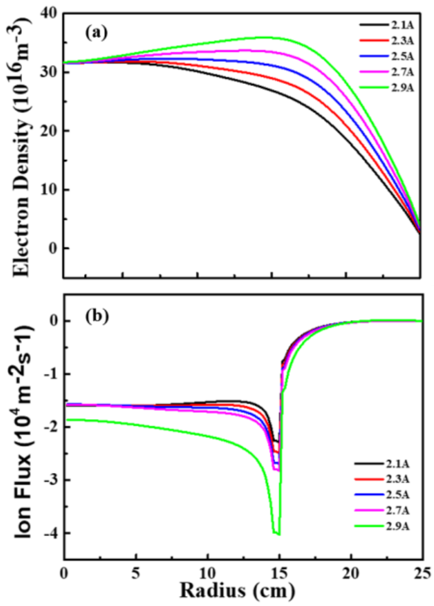

Fig. 2. Radial distributions of the (a) electron density at the chamber center, and (b) ion flux at the substrate, for different outer coil currents.