§6. Role of Peripheral Vacuum Regions in the Control of ECR Plasma Uniformity

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Electron cyclotron resonance discharges have been used for processing plasma as well as acting as an ion beam source. A significant advantage of ECR plasma sources is their high electron density, which can be achieved at low gas pressures. A great interest has been directed toward the uniformity and the area of the plasma since the uniformity of ECR plasma usually depends on the experimental conditions. So far we have clarified [1] experimentally and numerically that the vacuum region plays an important role in the plasma uniformity. On the other hand, it is pointed out that the electron temperature in a conventional ECR plasma is a little high for plasma processing such as etching and it is hard to control the electron temperature in a wide range. There have been several attempts on the electron temperature control in an ECR plasma. However, the electron temperature control with keeping the high electron density, which is earnestly required from industry, has not been accomplished. Recently, we have succeeded in production of a low-electron-temperature ECR plasma with high electron density using 915 MHz microwave. Furthermore, it was found that the electron temperature in a 915MHz ECR plasma depends on the external conditions such as incident microwave power, gas pressure and magnetic field configuration. Here, we measured the electron temperature of a 915 MHz ECR plasma in detail and attempted to control the electron temperature by changing the external conditions. The relationship between the electron temperature and the spatial distributions of the power absorption of microwave was studied using numerical simulation to investigate the physical mechanism of low electron-temperature plasma production. Furthermore, based on the experimental and numerical results, a new simple method of the electron-temperature control for an ECR plasma was proposed [2].

The experiments were performed using a cylindrical chamber made of stainless steel with the inner diameter of 290 mm and the length of 1200 mm. The microwave of 915 MHz was introduced through the quartz window and the substrate holder was placed approximately 550 mm from the window. Nitrogen gas was introduced into the chamber at a total flow rate of 50sccm, and the operating pressure was selected to be 0.13−1.33 Pa. Six magnetic coils with a thickness of 100 mm and an inner diameter of 320 mm were placed adjacent to the chamber to control the magnetic field and its distribution. The resonant magnetic field for a frequency of 915 MHz was 0.0327 T and the position was set at 120 mm from the window. Microwaves were converted from the coaxial mode to the circular TM_{01} mode with a mode converter and were launched into the chamber. Microwave power could be varied up to 2.5 kW. The plasma parameters were measured with a three-dimensional movable Langmuir probe.

It was found that the electron temperature of the 915 MHz ECR plasma is easily controlled by changing the incident microwave power when the gradient in the magnetic field strength near the resonant zone is gentle. Especially, at the gas pressure of 1.13 mTorr, the electron temperature decreased from 7 eV to 2 eV as the microwave power was decreased from 2.5 kW to 0.5 kW. From the numerical simulations of the spatial profiles of the power absorption, it was found that the electron temperature in an ECR plasma changes with changing the spatial profiles of the power absorption, that is, the electron temperature is low when the power absorption takes place in a wide area and the electron temperature increases when the power absorption is concentrated. The experimental and numerical results suggest that the electron temperature in an ECR plasma is controlled by changing the gradient in the magnetic field strength near the resonant zone and/or the microwave frequency because the power absorption profile may be changed with changing the effective resonance zone width.

References

1) Y. Kawai and Y. Ueda, Surface and Coatings Technology, **131**,(2000)12
2) N. Itagaki et al., to be published.