内部アンテナによる高密度誘導結合プラズマ源の製作とドライエッチングへの応用

○松谷晃宏

東京工業大学　精密工学研究所

1 Introduction

Dry etching technique is an important process for optical devices fabrication such as semiconductor lasers and optical waveguides. We have used an inductively coupled plasma (ICP) etching system for the microfabrication of InP and GaAs based optical devices[1, 2]. In conventional ICP etching, the plasma is generated by applying power to a coil antenna set at the outside of a process chamber. In transformer coupled plasma (TCP) type that is a kind of ICP, the coil antenna is set on the dielectric window of process chamber. Therefore the plasma density often tends to be high at the lower part of the coil antenna and the plasma diffuses in the process chamber. We think that if an internal antenna is used for the generation of plasma, the high-density plasma is confined at the upper space of a sample stage. However, although there are some reports on_experiments using an internal antenna[3-5] and sputtering of metal atoms with an internal antenna,[6, 7] there is few investigation on the etching of compound semiconductor material using the plasma generated by an internal antenna.

In this paper, we report on the trial of ICP etching of InP using an internal coil antenna.

2 Experimental and Results

We used Samco RIE-101ip as an ICP etching system. Figure 1 shows the schematic diagram of the ICP system. The diameter of the two-turn internal coil antenna is 11cm and that of the external coil is 20cm. The thickness of the quartz top plate of a process chamber is 20mm. The internal antenna is coated with ceramics. The internal antenna is located 7 cm above the sample in the process chamber. We used an InP wafer as the sample tray. The outside of the tray was covered with Si wafer. We used Cl_2 as the etching gas. The discharge frequency is 13.56MHz. The substrate temperature is 180°C. Figure 2 shows the ion density of Ar plasma generated by the internal antenna and the external antenna versus an input ICP power. The ion density was measured by a double probe method placed 1cm above the sample. It is found that the ion density of the internal antenna is higher than that of the external antenna with the same input power. Figure 3 shows the etching rate of Cl_2 plasma generated by the internal antenna and the external antenna versus the input ICP power. The etching rate for the internal antenna is larger than that of the external antenna with the same ICP power. In addition, the etching rate for the plasma of 100W with the internal antenna is the almost same as that of 300W with the external antenna. We think that the increase of etching rate is due to the different behavior of neutral particles as well as the increase of the ion density. The investigation of neutral particles in internal antenna plasma is our future subject. Figure 4(a) and 4(b) show photographs of the discharged plasma formed with the external antenna and the internal antenna, respectively. The ICP power is 100W. It is found that although the external antenna plasma diffused in the whole space of the process chamber, the internal antenna plasma is well confined to the inside of the coil. We think that the increase of the etching rate and the ion density for the internal antenna is originated from the confinement of the plasma. Figure 5(a) and 5(b) show etching examples of InP with a chlorine flow rate of 1sccm and 2sccm, respectively. An ICP input power was 100W with the internal antenna. It is found that the etching profile and the roughness of bottom etching surface is improved by reducing the chlorine flow rate. Figure 5(c) shows an etching example of InP with a chlorine flow rate of 1sccm and an ICP input power of 100W using the external antenna plasma. The etching time is the same as samples shown in Fig. 5(a). It is found that the etching rate is much lower with the external antenna plasma. We think that the difference in the etching rate and the etching profile is originated from the difference of the plasma density. The slightly tapered profile could be improved by reducing a chlorine flow rate.

3 Summary

In summary, we demonstrated the ICP etching process by using a newly designed ICP etcher with an internal antenna. It is found that the internal antenna induced plasma is well confined in the inside of the coil. It is found that the ion density of the internal antenna is higher than that of the external antenna with the same ICP power. The etching rate with an internal antenna plasma of 100W is the almost same as that with an external antenna plasma of 300W. Although it is better to use the antennas with the same size for comparison, we used different sizes for internal and external antennas. This is due to our machine’s limit for matching adjustment of plasma under the same etching condition. However, we believe that the obtained result shows that the internal antenna is more effective than the external antenna because of the plasma confinement and the increase of plasma density under the same etching conditions._The ICP etching using the internal antenna will become an effective technique for high-speed etching and electric power saving by optimizing the etching conditions.

References

1) A. Matsutani, H. Ohtsuki, F. Koyama and K. Iga: Jpn. J. Appl. Phys. **38** (1999) 4260.
2) A. Matsutani, H. Ohtsuki, F. Koyama and K. Iga: Jpn. J. Appl. Phys. **39** (2000) 1435.
3) H. Sugai, K. Nakamura and K. Suzuki: Jpn. J. Appl. Phys. **33** (1994) 2189.
4) M. Kanoh, K. Suzuki, J. Tonotachi, K. Aoki and M. Yamage: Jpn. J. Appl. Phys. **40** (2001) 5419.
5) P. Cicman and H. Fujita: Jpn. J. Appl. Phys. **41** (2002) 3114.
6) Y. Matsuda, Y. Koyama, M. Shinohara and H. Fujiyama, The 20th Symposium on Plasma Processing, P2-8 (2003) 241.
7) K. Nakamura, H. Suzuki and S. Ikezawa, The 20th Symposium on Plasma Processing, P2-14 (2003) 253.

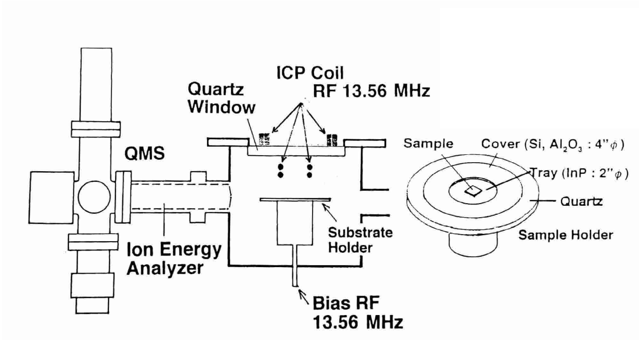


Fig. 1 Schematic diagram of the ICP

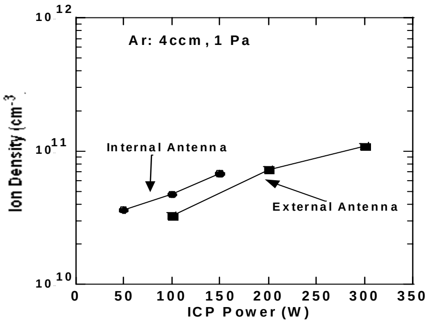
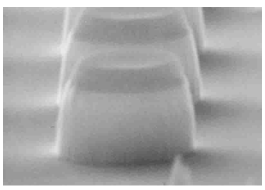


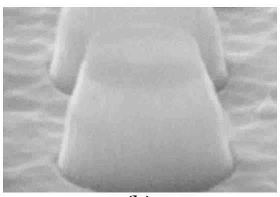
Fig. 2 Relationships between the ICP power the ion density of Ar plasma generated by the internal antenna and the external antenna.

(a) (b)

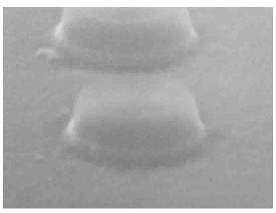
Fig. 4 Photographs of plasma for the external antenna (a) and the internal antenna (b).



(a)



(b)



(c)

1 μm

Fig. 5 Etching examples of InP in the same etching time for chlorine flow rate of 1sccm (a) and 2sccm (b) using the internal antenna plasma and that of 1sccm using the external antenna plasma (c). The ICP power is 100W.

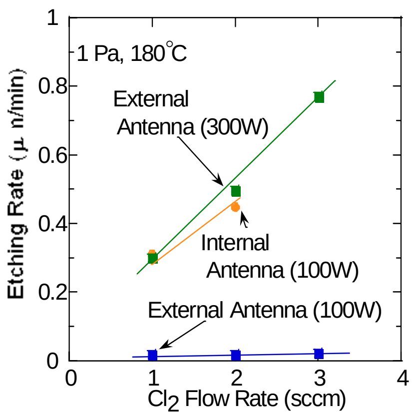


Fig. 3 Relationships between the ICP power and the etching rate of Cl_2 plasma generated by the internal antenna and the external antenna.