Cryo-ICP Etching System “RIE-800iPLN” for -150°C Process

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Introduction

As semiconductor chip patterns become finer and more highly layered, the requirements for etching process is getting more challenging in etch rate, aspect ratio, and selectivity to the mask. Cryo-etching has been attracting attention for its potential to realize anisotropic etching with high aspect ratio by increasing the etching rate of Si and SiN, increasing the selectivity to the mask, and forming a protective film on the sidewalls.[1,2] This report introduces a newly developed Cryo-ICP etching system, RIE-800iPLN, which enables etching at cryogenic temperatures below -150°C using liquid nitrogen.

RIE-800iPLN

RIE-800iPLN Features

The RIE-800iPLN is based on the ICP etching system “RIE-800iP”, which has been extensively marketed by Samco. The RIE-800iPLN has modified in the following three key points.

1. Substrate stage electrode with vacuum insulation for extreme low temperature
2. Liquid nitrogen supply system for cryogenic temperature
3. Hot nitrogen supply system for temperature control

1. The substrate electrode featuring a vacuum insulation structure is configured to achieve cryogenic temperatures, below -150°C. of the substrate stage of the conventional RIE-800iP is susceptible to moisture condensation and a significant buildup of frost, due to its insufficient thermal insulation. The RIE-800iPLN has a vacuum-insulated structure on substrate stage and can preclude condensation and/or a buildup of frost on the surface of the lower electrode, even exposed to the extreme low temperature of liquid nitrogen.
2. The cryogenic configuration by a liquid nitrogen supply system is designed to cool down the lower electrode to -150°C. The RIE-800iPLN is designed for the flow of liquid nitrogen at -196°C to achieve cryogenic temperatures. The liquid nitrogen flow is controlled by a PID control system and achieve stable control at cryogenic temperatures, down to -150°C.
3. Hot nitrogen supply system enables better temperature control from -50°C to -150°C than temperature control by only liquid nitrogen. It is difficult to control temperature in a range higher than that of liquid nitrogen, such as -50°C, only by adjusting the flow of liquid nitrogen. The RIE-800iPLN has hot nitrogen supply to the lower electrode and the combination of liquid and heated nitrogen enables wafer temperature control in the range of -50°C to -150°C.

Temperature control experiment results

Figure 1 shows the transition of wafer temperature and lower electrode temperature during cooling to cryogenic temperatures. Both the lower electrode and wafer temperatures fell below -150°C within 30 min from the start, and the lower electrode temperature and wafer temperature were cooled down to -179.5°C and -170.3°C, respectively. Furthermore, it showed a good temperature uniformity of within ±3°C in the vicinity of -170°C at five points within the ø8 inch wafer plane, while it showed a uniformity of about ±15°C in the relatively high temperature region.

Figure 2 shows the data obtained when the lower electrode was controlled in the -25°C to -150°C range with the supply pressure of hot nitrogen at 0.02 MPa and the temperature at 100°C. The temperature of the lower electrode was controlled in the range of -50°C to -150°C by balancing the liquid nitrogen cooling and the hot nitrogen heating. Since it takes more than 30 min to recover from overshoot in the -25°C temperature range, it is considered necessary to increase the temperature and supply pressure of hot nitrogen.

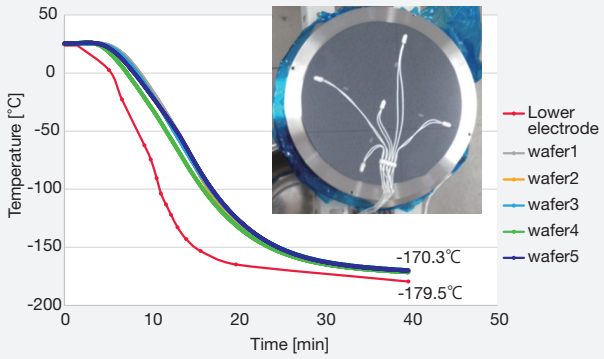

Figure 1. Lower electrode and wafer temperature

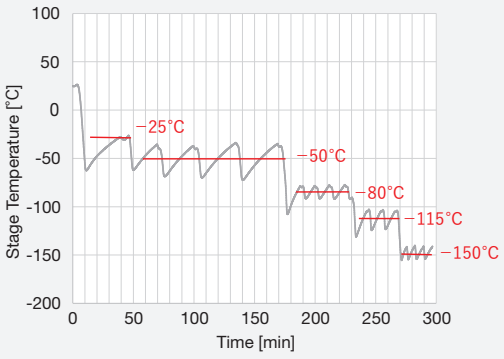

Figure 2. Temperature control ability

Cryogenic etching results

A chip sample was grease-attached on an ø8 inch Si wafer with thermal oxide film and etched with CHF_3. The backside helium pressure was set at 1,000 Pa. Figure 3 shows that the etch rate at -100°C is more than 30 % higher than that at higher temperature

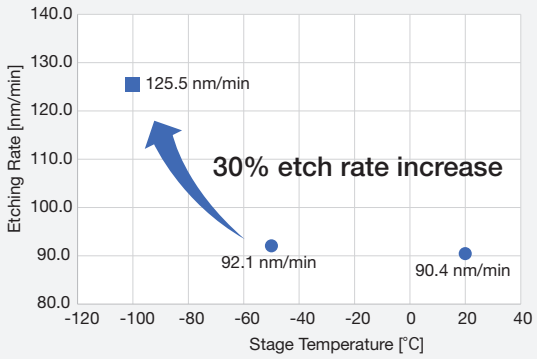

Figure 3. Stage temperature vs thermal oxide etching rate

Conclusion

The RIE-800iPLN was introduced in this report. It can cool the wafer down to -150°C or lower, and can control the wafer temperature the range of -50°C to -150°C. Additionally, it demonstrated higher etching rates of thermally oxidized SiO_2 at -150°C. Samco will study further the effectiveness of Cryo-ICP etching technology for the compound semiconductor field and promote its development.

References

1) R.Dussart, T.Tillocher, P.Lefaucheux and M Boufnichel, *J. Phys. D: Appl. Phys.*, 47, (2014) 123001.

2) B.Wu, A.Kumar, and S.Pamarthy, J. Appl. Phys., 108, (2010) 051101.

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