Plasma Enhanced Atomic Layer Deposition for AlOx

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Abstract: The AlO_x deposition was performed using PEALD system with the ICP coils. The thickness uniformity in 8 inch area less than ±2% was achieved by PEALD using O_2 plasma. The thickness uniformity of thermal ALD using H_2O or O_3 was also less than ±2%. The growth per cycle of AlO_x deposition using O_2 plasma is higher compared to deposition using H_2O or O_3.

Keywords: ALD,PEALD, AlO_x, ICP

1. Introduction

Semiconductors become smaller and thinner, and ALD (atomic layer deposition), is becoming increasingly important because ALD enables nano-level film thickness control and excellent step-coverage, [1,2]. Insulating oxide films, such as AlO_x and SiO_2, have been the most popular materials by ALD. However, in recent years, ALD application has been expanding to various materials, such as nitrides, metals, and conductive films. Such materials require ALD systems to accommodate the precursors of low vapor pressure and conductive films deposition in the chamber. The low vapor pressure of precursors leads to the difficulty to purge the precursors as they easily adsorbs on the chamber wall and the exhaust pipes. The conductive film deposition leads to another difficulty. The deposited conductive films on the insulator may connect the RF electrode and grounded chamber lid electrically. Furthermore, it is difficult to deposit the conduction films conformally on the high aspect ratio structure because the radicals of H_2 plasma or NH_3 plasma are easily deactivated before they arrive at the bottom.

In this study, we developed the novel chamber structure and plasma source to resolve the challenges stated above and analyzed the film properties.

2. Experiments

The novel ALD system, Samco AD-800LP, is a load-locked ALD system and has three features below.

The first feature is reaction chamber heating. A cartridge heater in the reaction chamber efficiently heat the entire reaction chamber uniformly. The exhaust piping is also heated to avoid cold spots and prevent the condensation of low vapor pressure precursors.

The second feature is the ICP coil. Fig.1 shows a schematic diagram of the ALD reaction chambers. In the conventional ALD system, the RF electrode is installed on the upper side of the reaction chamber. The deposition of conductive films such as metal or TiN may coat the surface of the insulating plate and cause the short circuit between RF electrode and grounded chamber lid. The AD-800LP has the ICP coil located outside the reaction chamber to prevent the short circuit between the RF electrode and the reaction chamber lid, while enabling high-density plasma. Furthermore, a slitted top plate is employed to prevent the insulating plate from being covered by conductive films and blocking the magnetic field.

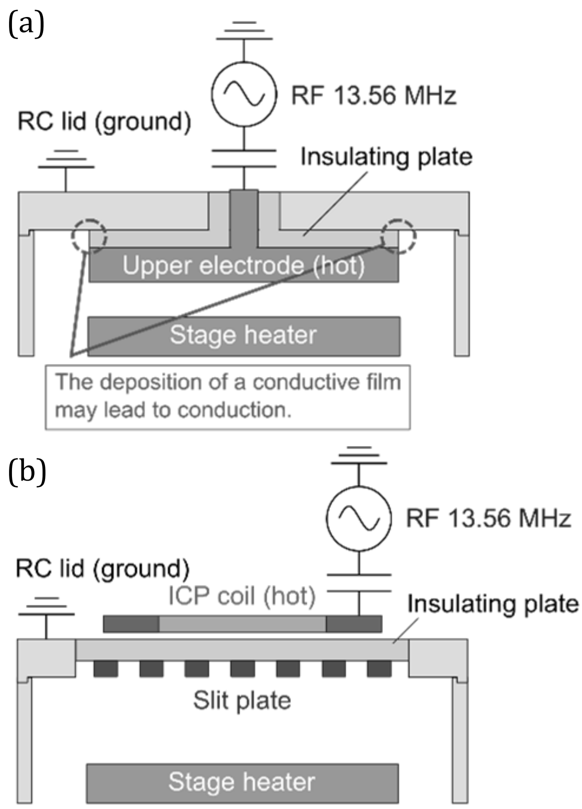

Fig.1 Schematics of (a) the conventional PEALD system and (b) the novel PEALD system

The third feature is the easy replacement of the reaction chamber for maintenance. Because ALD has excellent coverage properties, even if protective shields are installed on the reaction chamber, the films may get deposited on the back side of the plate and the inner wall of the reaction chamber. It is difficult to remove the films adhered to the reaction chamber wall. The capability to replace chamber on site enables the easy cleaning of the chamber wall and provides stable processes in the long-term.

We have performed AlO_x film deposition on an 8-inch Si wafer using the AD-800LP. The films were deposited using TMA (trimethylaluminum) and three oxidants: O_2 plasma, H_2O supply, and O_3 supply. The stage heater temperature was set at 300°C. The supply time of TMA, O_2plasma, H_2O, and O_3 was 0.03sec, 3sec, 0.3sec and 0.15sec, respectively. During O_2 plasma, the pressure was around 50Pa and the RF power was set to 100W. The film thickness was measured with an ellipsometer (HORIBA, Ltd., Auto SE).

3. Results

Fig.2 shows the thickness distribution of the AlO_x film deposition. The thickness uniformity was below 1 nm and there was no distribution trend. This suggests that the distribution due to measurement error.

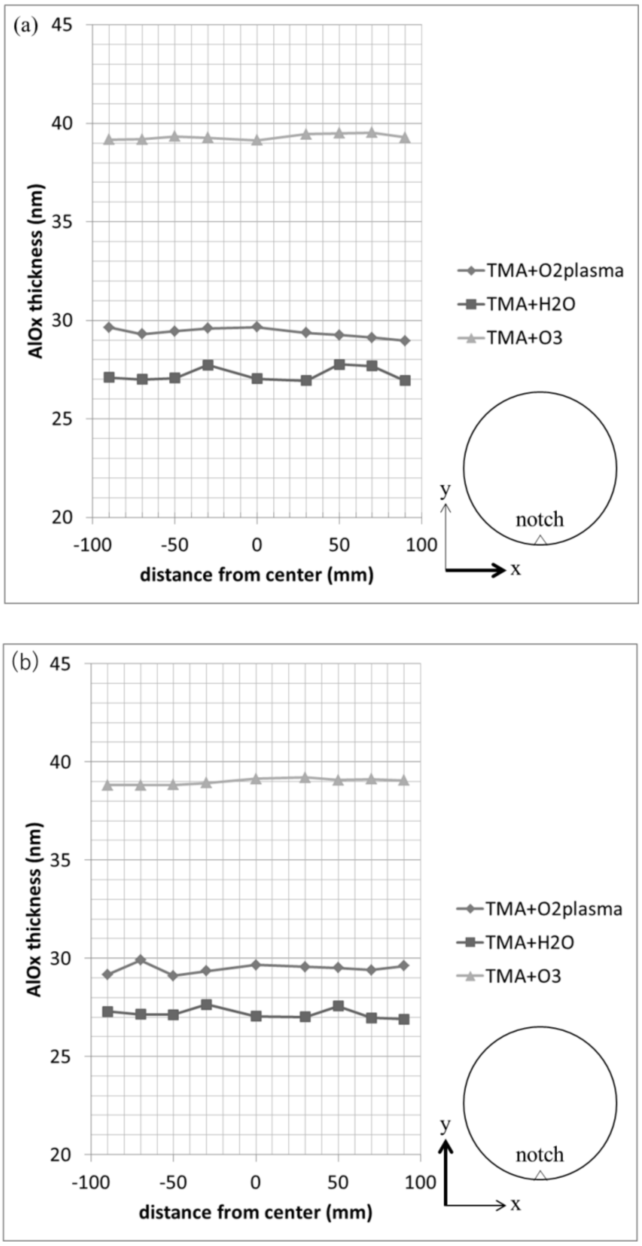

Fig.2 The thickness distribution of (a) x direction and (b) y direction.

Table 1. AlO_x deposition results

Oxidants	O_2 plasma	H_2O	O_3
Average thickness	29.42nm	27.22nm	39.16nm
Max thickness	29.90nm	27.77nm	39.53nm
Min thickness	28.96nm	26.90nm	38.81nm
Thickness uniformity	±1.6%	±1.6%	±0.92%
Cycle number	300cycle	300cycle	500cycle
Growth Per Cycle	0.098 nm/cycle	0.091 nm/cycle	0.078 nm/cycle

The summary of AlO_x deposition results were shown in Table.1. Excellent in-plane uniformity of less than ± 2% was obtained with all the oxidants. The growth per cycle is 0.07 to 0.1 nm / cycle. This indicates that film thickness control at the nano level is realized. The AlO_x deposition using O_2 plasma shows the highest growth per cycle.

4. Conclusion

The AlO_x film deposition was performed using the novel ALD system with replaceable heated chamber and ICP coils. The deposition with good thickness uniformity less than ±2% in 8 inch area is realized using the three oxidants. The growth per cycle of AlO_x deposition using O_2 plasma is higher compared to deposition using H_2O or O_3.

5. Acknowledgements

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6. References

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