Atomic Layer Deposition (ALD) System Development for Power Device Applications

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■ Introduction

ALD is a layer-by-layer thin film deposition method commonly used to produce gate insulators. The principle of ALD is repeated deposition of precursors to form a monolayer using self-limited reactions, and then oxidizing or nitrogenizing the monolayer.

Although ALD is limited by a range of temperatures known as a "temperature window", it still has the advantage over CVD, sputtering and other deposition technologies in terms of uniformity, atomic-level film thickness control and step coverage.

Samco released the new ALD system "AL-1" in September 2015 with a focus on gate insulator formation of GaN and SiC power devices, passivation layer deposition, as well as the MEMS field.

This report shows the AL-1's system specifications and several pieces of performance data.

■ Specifications

The AL-1 realizes layer-by-layer deposition by alternately supplying metalorganics and reactants (H_2O, O_3, O-radicals, etc.) into the reaction chamber. The inner wall heater, which is close to the chamber wall, prevents unwanted adsorption of the metalorganics and reactants on the wall surfaces. Furthermore, ALD valves that are capable of pulsing the aforementioned metalorganics and reactants with a precision of 10 msec are placed as close to the reaction chamber as possible. Such mechanisms are specifically designed to prevent particle problems and shorten vacuum and purge times.

The AL-1 is capable of depositing uniform oxides on one ϕ8-inch wafer or three ϕ4-inch wafers and is suitable for pilot production as well as R&D. Figure 1 illustrates the system's exterior.

Figure 1 AL-1 Exterior

Table 1 System Specifications Summary

Sample Sizes	ϕ4” wafer × 3, ϕ8” wafer × 1
Control System	PC User Interface
Stage Heating	Up to 500°C
Gas Lines	・TMA: $Al(CH_3)_3$ (via tank) ・H_2O (via tank) ・O_3 (via ozonizer) Max. ozone concentration 250g/Nm^3 (O_2 flow:200sccm) *For information about additional precursors, please contact us
Vacuum Line	Dry pump
Dimensions	Body: 900mm(W)×1300mm(D)×1355mm(H) Control box: 570mm(W)×630mm(D)×1576mm(H)

■ AL-1 Process Capability Results

The following data outlines the results of utilizing TMA (trimethyaluminum) and H_2O in order to deposit AlO_x (aluminum oxide). The ideal ALD temperature window for AlO_x deposition using these precursors ranges from 220°C to 350°C.

Figure 2 illustrates the correlation between film thickness and the number of cycles at a deposition temperature of 250°C. The results indicate that film thickness is proportional to the number of ALD cycles at 1.2 Å /cycle. This means precise thickness control is available at the atomic level.

Figure 3 demonstrates the relationship between deposition temperature and breakdown electric field, at a film thickness of 100nm. At 350°C, the breakdown electric field reaches 7.5 MV/cm. By optimizing the precursors and the reaction methods, 10 MV/cm at temperatures as low as 100°C may be possible in the future.

Finally, Figure 4 illustrates the coverage of AlO_x film that was deposited at 250°C over a hole with a diameter of 1.25µm, a depth of 40 µm, and an aspect ratio of 32. The AL-1 achieves excellent film coverage uniformity, as demonstrated by a film thickness of 103nm all along the hole's surface, sides, and bottom. AlO_x film deposited by the AL-1 is therefore optimal for trench MOSFET and T-gate devices.

Currently, Samco is collaborating with academic and government institutions in order to develop ALD processes suitable for GaN, SiC and Ga_2O_3 power devices. This involves confirming the characteristics of MOSFET and MOS-HFET devices that utilize AlO_x and also SiO_2 films produced by the AL-1, wherein Samco aims to develop a gate insulator deposition process to achieve low interface state, high breakdown voltage, and so on.

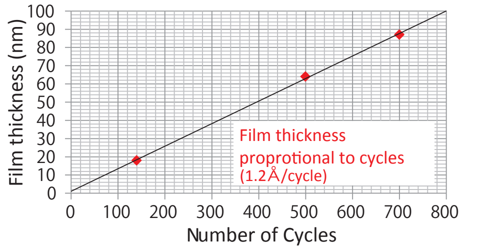

Figure 2 AlO_x film thickness control

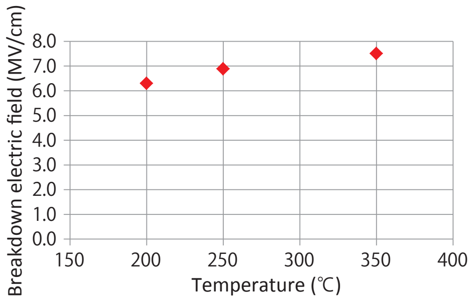

Figure 3 AlO_x film breakdown electric field

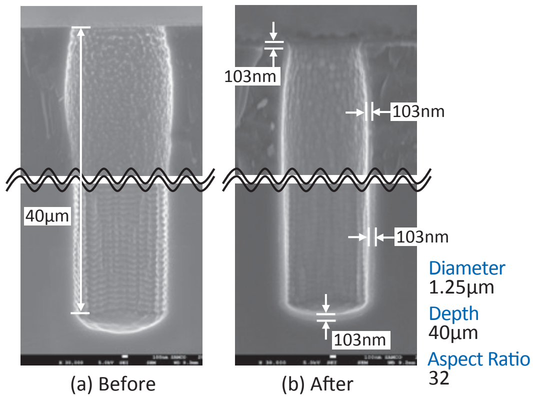

Figure 4 Step coverage of AlO_x film over hole pattern

■ Conclusion

As demonstrated by the above data, the AL-1 has many advantages that are characteristic of ALD, including film thickness control, high breakdown voltage and excellent step coverage on high-aspect structures. Going forward, we aim to contribute to the enhancement of our customers' electronic devices and next-generation power devices. For more information, please contact one of our representatives.

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