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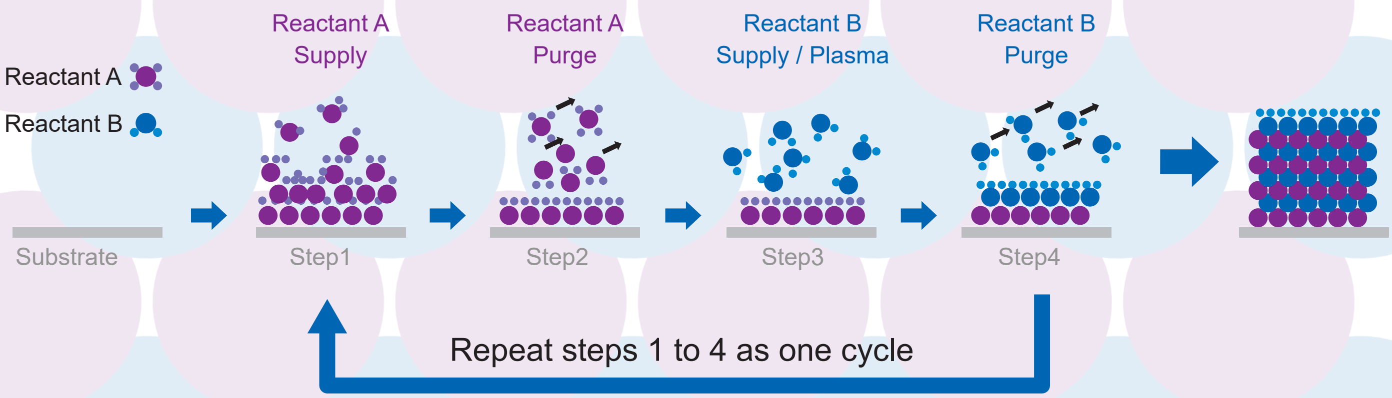
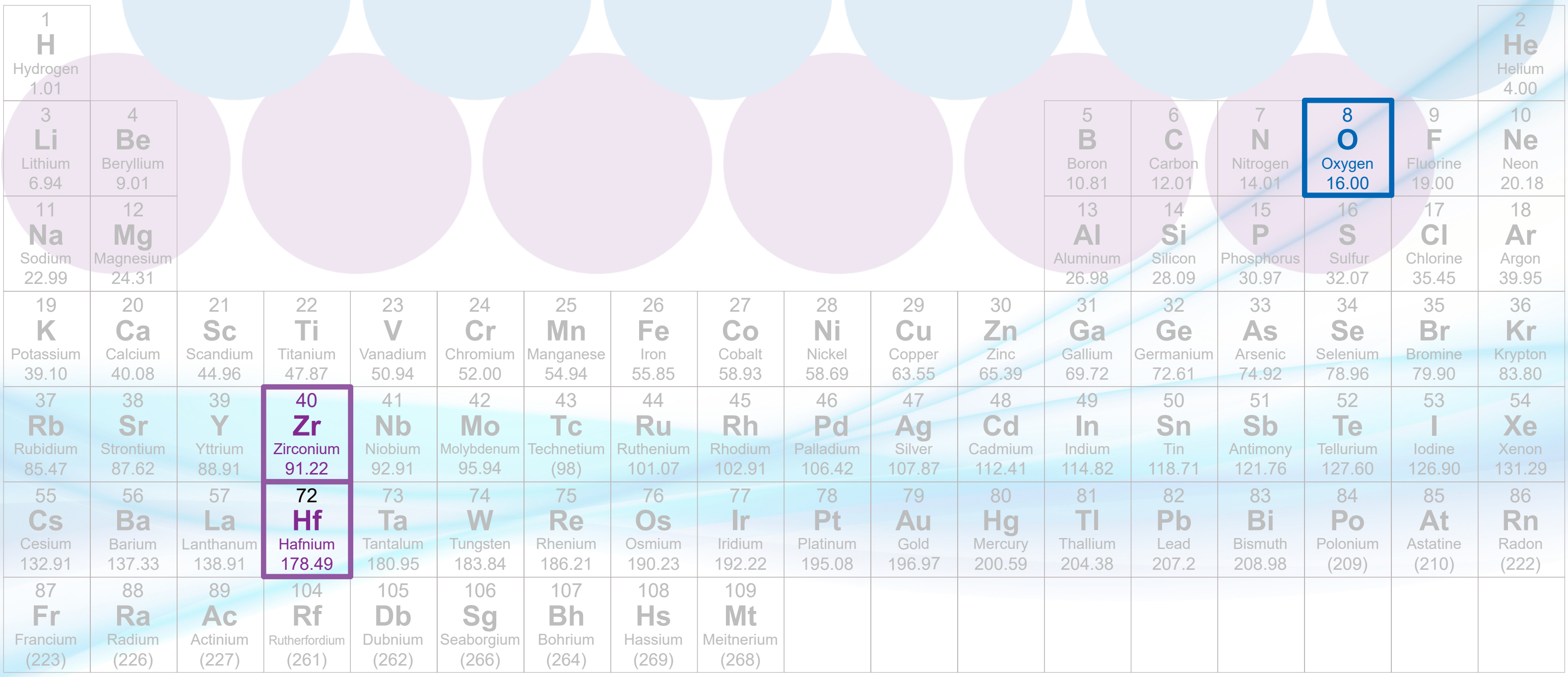
HfO_2 & ZrO_2 Film Deposition by ALD

Samco Inc. Technical Report vol.115 / October 2021



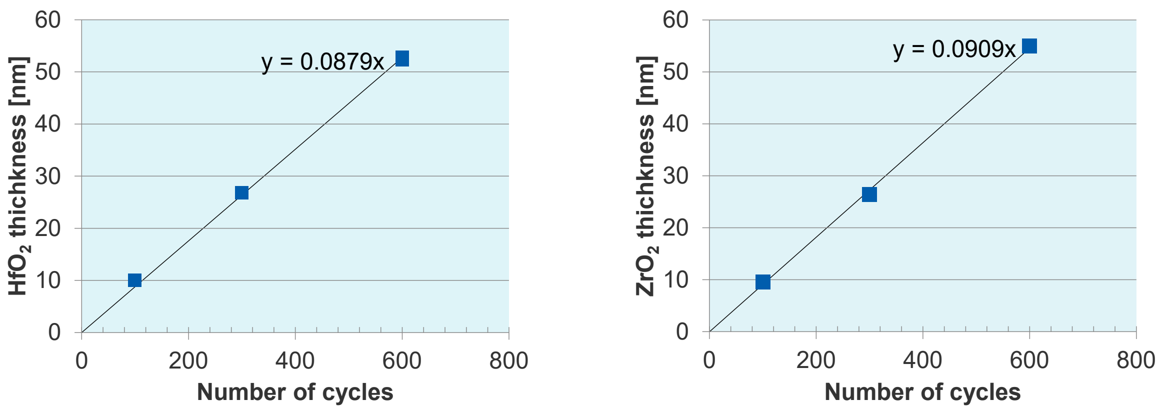


Introduction

HfO_2 and ZrO_2 are often applied as gate insulating films because of their higher dielectric constant compared to AlO_x and SiO_2. In addition, they show excellent chemical resistance and are used as a protective film against chemicals. HfO_2 and AlO_x multi-layer are also used as a water vapor barrier layer. Recent researches reported that HfO_2 films and mixed HfO_2 – ZrO_2 films of approximately 10 nm show ferroelectric properties, which is attracting attention for further research. Atomic Layer Deposition (ALD) enables excellent film thickness controllability and pinhole-free deposition and is suitable for deposition of ultra-thin films for gate insulators of FETs. In this report, we introduce the deposition of ALD-HfO_2 and ALD-ZrO_2 by the Samco thermal ALD system model "AL-1".

Film Thickness Controllability

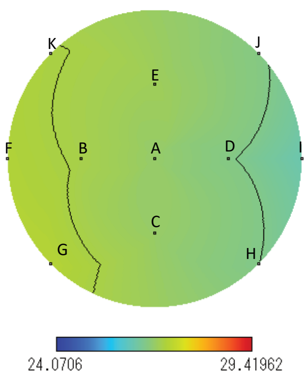
HfO_2 and ZrO_2 films were deposited on a Si substrate using TEMAHf (Tetrakis (ethylmethylamino) hafnium), TEMAZr (Tetrakis (ethylmethylamino) zirconium) and H_2O. The film thickness was measured by an ellipsometer. Figure 1 shows the relationship between the number of cycles and the film thickness deposited at 250℃. The film thickness increased in proportion to the number of cycles with 0.08 to 0.10 nm / cycle. Therefore, the film thickness was well controlled on the order of nanometer or less.



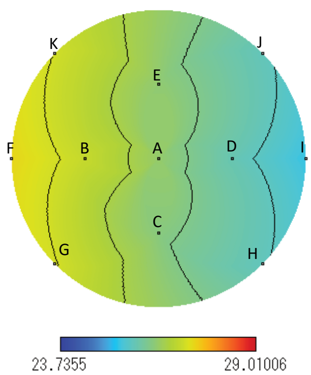
(a) HfO_2 (b) ZrO_2

Figure 1. The number of cycles vs the film thickness of (a) HfO_2 and (b) ZrO_2

Additionally, the film uniformity was measured by placing Si chip samples on a ø230 mm carrier tray. The results are shown in the Figure 2. The thickness uniformity of the HfO_2 and the ZrO_2 film were ± 1.7% and ± 3.8% respectively when depositing the films of approximately 26.5 nm. The refractive index at λ = 633 nm is 2.077 to 2.093 for the HfO_2 film and 2.135 to 2.155 for the ZrO_2 film. The ZrO_2 shows a slightly higher refractive index than HfO_2.



	Film thickness [nm]	Refractive index @633 nm
A	26.7	2.093
B	27.0	2.092
C	26.8	2.087
D	27.0	2.092
E	26.8	2.086
F	27.1	2.093
G	27.1	2.083
H	26.5	2.080
I	26.2	2.088
J	26.5	2.082
K	27.0	2.077
Ave.	26.7	2.087
Unif.	± 1.7%	± 0.5%



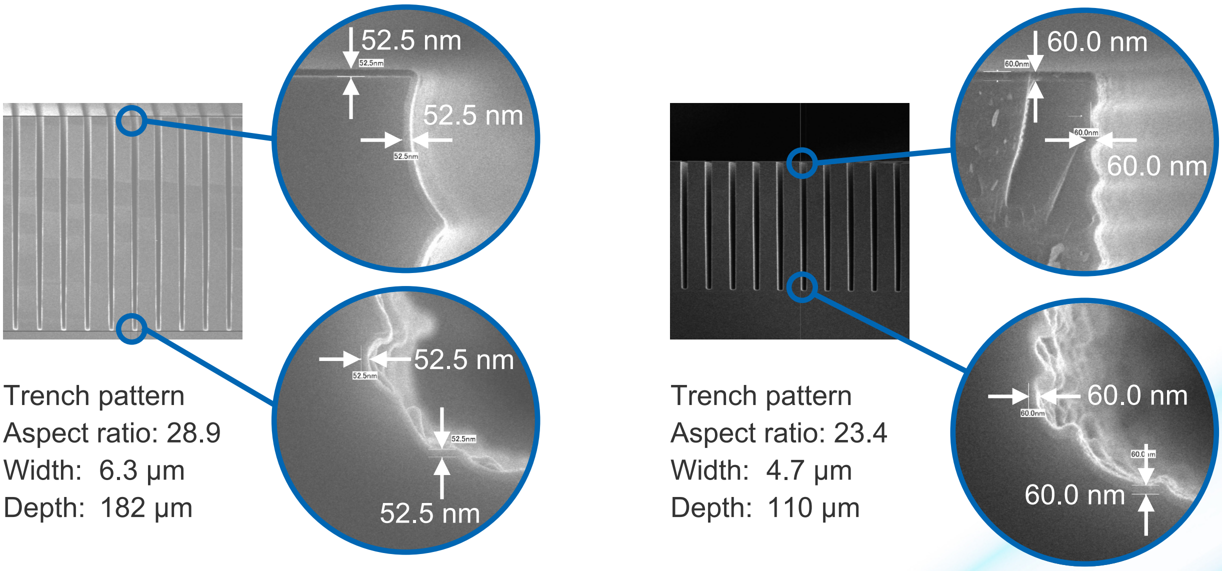
	Film thickness [nm]	Refractive index @633 nm
A	26.4	2.149
B	27.0	2.149
C	26.2	2.142
D	25.8	2.155
E	26.3	2.153
F	27.3	2.149
G	27.1	2.137
H	25.7	2.149
I	25.3	2.141
J	25.7	2.135
K	27.1	2.153
Ave.	26.4	2.147
Unif.	± 3.8%	± 0.5%

(a) HfO_2 (b) ZrO_2

Figure 2. Film thickness and refractive index @ 633 nm uniformity of (a) HfO_2 and (b) ZrO_2

Step Coverage

The step coverage on a high aspect ratio structure is examined. The Si samples with trenches of an aspect ratio over 20 were prepared using Samco's Si DRIE system model: RIE-800iPB. The figure 3 shows the cross-sectional SEM images of the HfO_2 and ZrO_2 deposited at 250℃. Both HfO_2 and ZrO_2 were uniformly deposited from the top to the bottom of the trench pattern. In addition, the film traced the trench surface scallops fabricated by the Bosch process. These show the excellent step coverage – one of superior characteristics of ALD.



(a) HfO_2 (b) ZrO_2

Figure 3. Cross-sectional SEM images of (a) HfO_2 and (b) ZrO_2 deposited on a high aspect ratio trench.

Conclusion

In this report, we introduced the HfO_2 and ZrO_2 deposition using the thermal ALD system model AL-1. The results show the excellent film thickness controllability and step coverage on the both films. We continue to evaluate performance of the ALD processes applied to a variety of devices and keep providing more solutions to realize customers' requirement.

Thermal ALD System

AL-1

Better Tomorrow Driven by Thin Film Technology

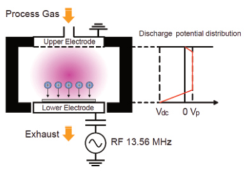
From Kyoto to the forefront of semiconductor processing,
Samco's systems lead the way in Advanced Thin Film Technology

Production and R&D teams – working in automobile safety, biotechnology, renewable energy, and other high-tech fields – can't afford to be without reliable process equipment and support.
Samco's durable systems, world-class recipe database and prompt service help you minimize downtime, and boost cleanroom productivity, while cutting costs at the same time.
We give teams reliable tools and resources, enabling your business or organization to push the limits of Thin Film Technology.

Four Pillars of Samco Deposition Systems

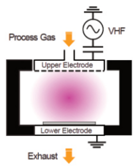
Cathode PECVD

- 13.56 MHz is applied to the lower electrode to utilize the ion energy obtained from the sheath electric field on the cathode electrode
- Thick films can be deposited at high speed and low temperatures
- For SAW devices, optical waveguides, etc.



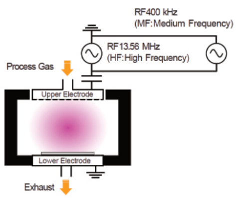
VHF-PECVD

- VHF bands such as 27, 40, and 60 MHz can be applied to the upper electrode to deposition with abundant radicals
- Low-damage deposition for RF devices
- For high-speed deposition of μc-Si



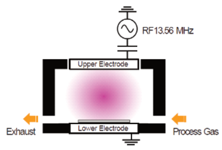
Dual-frequency PECVD

- A wide process window is achieved by applying dual frequencies of 13.56 MHz and 400 kHz to the upper electrode.
- Excellent controllability of film stress
- For compound semiconductors, electronic devices



PE & Thermal ALD

- One atomic layer is deposited by repeating the supply of precursor and purging of excess precursor.
- Excellent step coverage
- For gate oxides for electronic devices



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