AN 416
Thin Film Hafnium Silicate (HfSiO) Thickness and Composition Measurements by XPS

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Discussion

Ultra thin high-κ dielectric films using hafnium silicates (HfSiO) provide an increased dielectric constant compared to SiO_2 and in general, avoid the growth of SiO_x interface layers and low recrystallization temperatures associated with HfO_2. However, since HfSiO is a ternary (actually a psuedo-binary) material, the tailoring of the material to provide the right EOT (equivalent oxide thickness) requires precise control of composition, stoichiometry [i.e. Hf:Si ratio and O:(Hf+Si) ratio], and layer thickness. A *HfSiO High Precision XPS Measurement* has been developed that can provide all this information in a single measurement with the accuracy and precision required for sub-50Å dielectric films.

Device and process engineers, process development groups, and deposition tool manufacturers are required to know, monitor, and control process conditions for HfSiO film properties. Because physical film properties (i.e., thickness, stoichiometry, composition) can affect electrical and performance properties (such as EOT, flat band offsets, yield, etc.) it is insufficient to monitor only one parameter for dielectric layer deposition and growth. Process development groups and deposition tool groups especially need to measure multiple dielectric film properties to enable good process control and design and verify good deposition tool performance.

The *HfSiO High Precision XPS Measurement* provides HfSiO dielectric layer thickness, Hf:Si ratio, O:(Hf+Si) ratio, and composition in a single and precise measurement. The high reproducibility of the measurement makes it valuable for checking wafer-to-wafer and lot-to-lot uniformity of HfSiO dielectric films. This measurement is particularly suited to blanket films and can be used to spot check different wafer locations and wafer uniformity (radial or diameter scan). To illustrate the short term reproducibility, Figure 1 shows the measurements of HfSiO thickness, Si:Hf ratio, and O:(Si+Hf) ratio for 21 repeat measurements on a single area of a thin HfSiO film on a Si wafer. Table 1 shows a summary of the average, one standard deviation and one Relative Standard Deviation (RSD) for these repeated measurements.

Because the measurement also provides compositional information, it is well suited for monitoring in-layer contamination (e.g. F, C, Cl, etc.) and process tool cleanliness. An example of this is shown in Table 1 where trace levels of Zr and F are also detected.

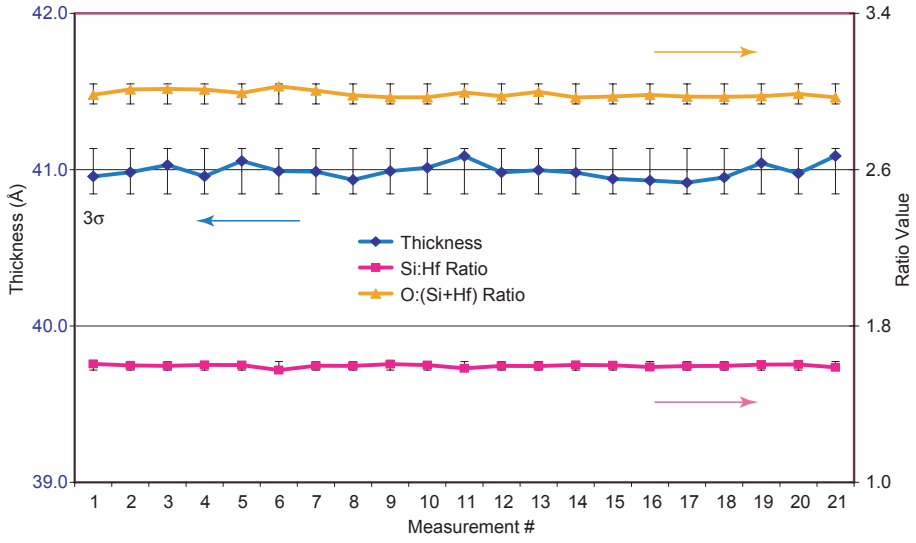

Figure 1. Thickness and Stoichiometry repeatability in 21 consecutive measurements on a thin HfSiO film on Si

Table 1. Thickness, Stoichiometry and Composition reproducibility in 21 consecutive measurements on a thin HfSiO film on Si

Layer Thickness	Average	Std. Dev. (1σ)	RSD%
Thickness (Å)	42.77	0.11	0.26
Stoichiometry	**Average**	**Std. Dev. (1σ)**	**RSD%**
Si:Hf Ratio	1.60	0.01	0.51
O:(Si+Hf) Ratio	2.97	0.03	0.87
Composition	**Total Atomic Concentration**		
C at%	5.4	0.50	9.2
O at%	65.2	0.29	0.4
Si at%	20.8	0.23	1.1
Hf at%	8.6	0.07	0.9
Zr, F at%	<0.2	-	-

It must be stressed that HfSiO layer properties, (i.e., physical thickness, stoichiometry and composition) do not necessarily correlate to one another. For example, it is possible to have near perfect stoichiometric values across an entire wafer, yet the thickness can vary independently of the stoichiometry and therefore the EOT and yield will vary significantly. An example of this is found in Figure 2. Here, the Si:Hf ratio and the O:(Hf+Si) ratios remain relatively uniform over an 80mm radial line. The thickness, on the other hand, decreases over this same line. Similarly, one can have an apparent uniform thickness across a wafer, but with varying stoichiometry. The latter case would similarly affect the dielectric constant, and hence, the EOT and yield will vary across the wafer.

Since different critical film properties (thickness, stoichiometry, and composition) can vary independent of one another, it is crucial to be able to monitor all of these properties to insure that the films are within tolerance. The HfSiO High Precision XPS Measurement has been demonstrated to provide this analysis.

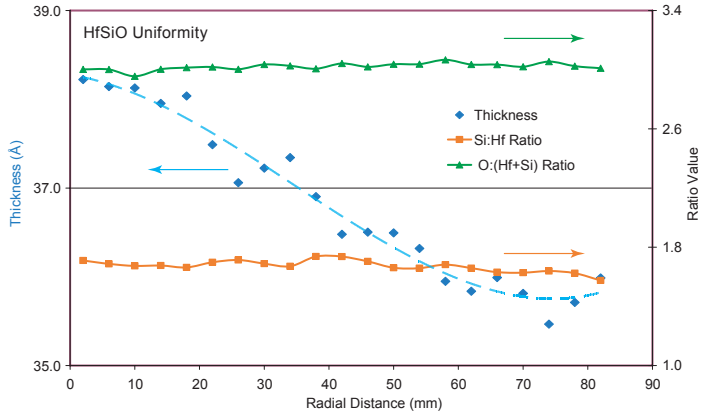

Figure 2. Thickness and Stoichiometry uniformity over an 80mm radial distance of a thin HfSiO film on Si

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