AN 412
Accuracy in SiON Thickness and N Dose Measurements by XPS

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Summary

In summary, a series of comparisons have been performed between the SiON High Precision XPS Measurement and other analytical methods for both SiON thickness and N dose. The agreement between methods among all of the comparisons is good. Although none of the methods described can claim to give the “absolute” correct values, these results offer confidence that the SiON High Precision XPS analysis provides both measurements using a single technique while obtaining results comparable to those from all other techniques applicable for measuring these characteristics of SiON gate dielectric films.

Discussion

SiON gate dielectric films for 130 nm, 90 nm and 65 nm node IC devices must be tightly controlled in both thickness and nitrogen dose, because these variables can not only be independent from one another, but each alone can affect the device performance. The SiON High Precision XPS Measurement has been developed to address these requirements, i.e., independent, high precision measurements of thickness and nitrogen dose in SiON gate dielectric films.

However, the accuracy of an analytical measurement is sometimes a point of discussion, especially when NIST traceable reference materials are unavailable. In this instance a comparison to other analytical methods can be helpful to build confidence in the measurement. The SiON High Precision XPS Measurement for SiON thickness and N dose is compared below to ellipsometry, TEM, NRA (Nuclear Reaction Analysis) and SIMS.

For thickness comparison to ellipsometry, thin SiO_2 films were used since ellipsometry measurement of SiON films is unreliable. Table 1 (upper half) shows the comparison for three samples with thicknesses ranging from 5 to 24 Å. The agreement is good between the two techniques.

For thickness comparison to TEM, SiON films were used. The TEM cross sections for four SiON films are shown in Figures 1 to 4. The comparison of the thickness values between TEM and XPS is shown in Table 1 (lower half) for thicknesses ranging from 17 to 56 Angstroms. The thickness values are consistent between the two techniques. Note that the TEM thickness values depend upon where the “interface” and “top surface” of the SiON film are defined (see Figures 2 and 4). For a 15Å SiON film the distance between these two planes can vary by 10-30% across the TEM section image. In contrast the SiON High Precision XPS Measurement of SiON thickness has a precision <1% RSD.

Table 1. Thickness Comparison: High Precision XPS, Ellipsometry and TE

	SiO_2 High Precision XPS and Ellipsometry	
SiO_2	XPS (wafer center)	Ellipsometry (nominal wafer avg.)
Wafer A	5.55 Å	6.0 Å
Wafer B	15.66 Å	16.1 Å
Wafer C	24.30 Å	24.5 Å
	SiON High Precision XPS and TEM	
SiON	XPS	TEM
Wafer D	17.40 Å	18 Å
Wafer E	24.74 Å	27 Å
Wafer F @ 0,10mm	46.83 Å	43 Å
Wafer F @ 0,90mm	56.35 Å	54 Å

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For a N dose comparison to NRA, four SiON samples with N doses ranging from 6E14 atoms/cm^2 to 2.5E15 atoms/cm^2 were used. The results are shown in Table 2. Again, good agreement exists between the two techniques.

For a N dose comparison to SIMS, a low dose nitrogen implant into SiO_2 was used. The result is shown in Table 3. Good consistency is found between SIMS and the XPS measurement for N dose.

In summary, a series of comparisons have been performed between the SiON High Precision XPS Measurement and other analytical methods for both SiON thickness and N dose. The agreement between methods among all of the comparisons is good. Although none of the methods described can claim to give the “absolute” correct values, these results offer confidence that the SiON High Precision XPS analysis provides both measurements using a single technique while obtaining results comparable to those from all other techniques applicable for measuring these characteristics of SiON gate dielectric films.

Table 2. N Dose Comparison: SiON High Precision XPS and NRA

	Thickness (Å)	XPS (atoms/cm^2)	NRA (atoms/cm^2)	NRA Precision
Wafer D	17.33	6.37E+14	6.90E+14	(+/-0.69E+14)
Wafer G	26.39	2.99E+15	2.42E+15	(+/-0.24E+15)
Wafer E	24.74	5.86E+15	4.77E+15	(+/-0.48E+15)
Wafer H	18.73	2.53E+15	2.04E+15	(+/-0.20E+15)

Table 3. N Dose Comparison: SiON

	Thickness (Å)	XPS (atoms/cm^2)	SIMS (atoms/cm^2)
Wafer I	43.38	3.57E+14	3.70E+14

TEM Cross Section

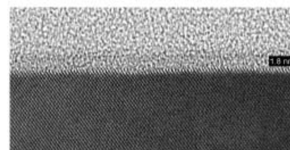

Figure 1. Wafer D

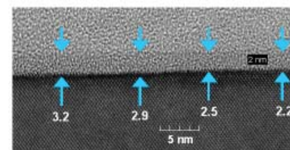

Figure 2. Wafer E

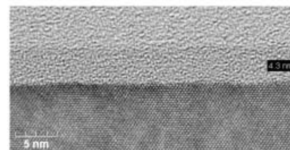

Figure 3. Wafer F @ 0,10mm

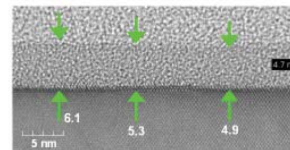

Figure 4. Wafer F @ 0,90mm

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