AN 413
Precision and Wafer Uniformity in SiON Thickness and N Dose Measurements by XPS

May 7, 2007 (Version 3.0)

Discussion

SiON gate dielectric films for 130 nm, 90 nm and 65 nm node IC devices must be tightly controlled in (1) thickness and (2) nitrogen dose, because both parameters can be independent of each other while affecting the device performance. The requirement for tight control in these physical parameters means the precision of each measurement must be < 1% RSD (One Relative Standard Deviation). Only the SiON High Precision XPS Measurement meets these requirements, i.e., independent measurements of thickness and nitrogen dose, at high precision.

An example of the SiON High Precision XPS Measurement capability is shown in Figures 1 and 2, where a 60 point radial line scan of a 200 mm wafer, reveals a radial non-uniformity in both thickness and N dose. The thickness varies from about 4.75 nm to about 5.65 nm and the N dose varies over an order of magnitude, from about 2E14 atoms/cm^2 to 2.5E15 atoms/cm^2. This may be an extreme case, but the smoothness of the data in Figure 2 illustrates the excellent short term precision (<< 1% RSD), which would be needed, for example, to distinguish sub-Angstrom differences in thickness with statistical confidence.

The data in Figure 2 suggest there is a correlation between the thickness and N dose, i.e., that they are not truly independent of each other. However, a typical correlation curve for N dose versus SiON thickness is shown in Figure 3, and here we see that a non-linearity in the correlation exists at the higher thicknesses (and corresponding lower N doses). Other measurement methods that provide a single piece of information, such as N concentration, are also not reliable as process monitors. In Figure 4 we also see a non-linearity in N dose versus N concentration. These data reinforce the need to measure both N dose and SiON film thickness independent of each other. A technique used to measure only one of the two parameters, and which is assumed to correlate in some way to the other parameter, can result in missing an out-of-control process.

As indicated earlier the short term precision of the SiON High Precision XPS Measurement is << 1%. The long term precision of the measurement is shown in Figure 5 for a single wafer measured over a one year period. The long term RSD for the thickness is 0.82% and for the N dose is 0.98%. These are consistent with, and the figure also suggests, a short term RSD <<1%.

In summary, the SiON High Precision XPS Measurement for SiON is capable of independently measuring both the SiON thickness and N dose with excellent precision. This capability is essential in developing and controlling the equipment and processes for thin (typically less than 100Å) SiON gate dielectric films.

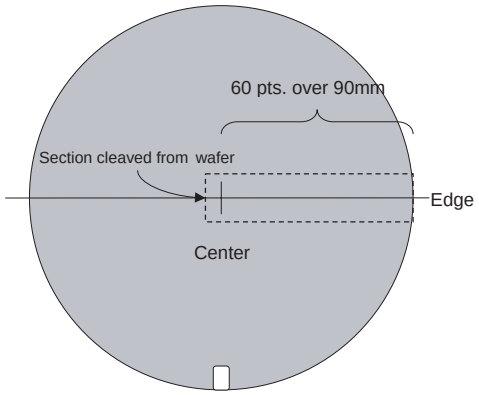

Figure 1. 200 mm SiON Wafer

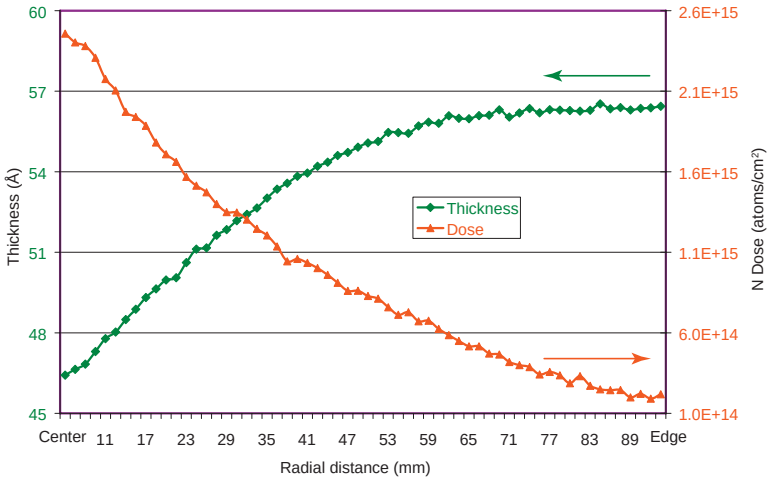

Figure 2. Thickness & N Dose Uniformity 200 mm Wafer

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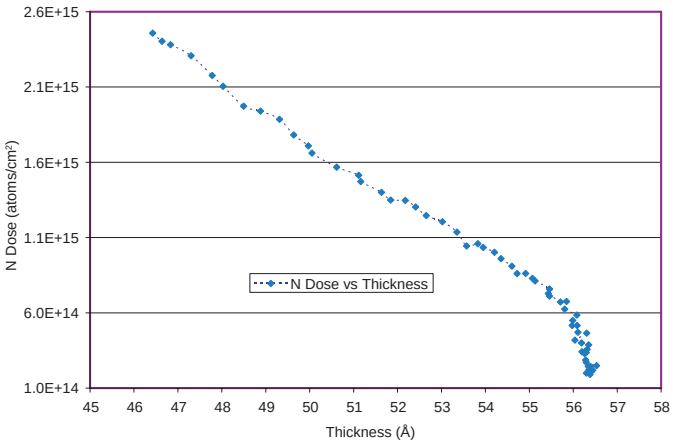

Figure 3. N Dose vs. Thickness Correlation Curve on a 200mm Wafer

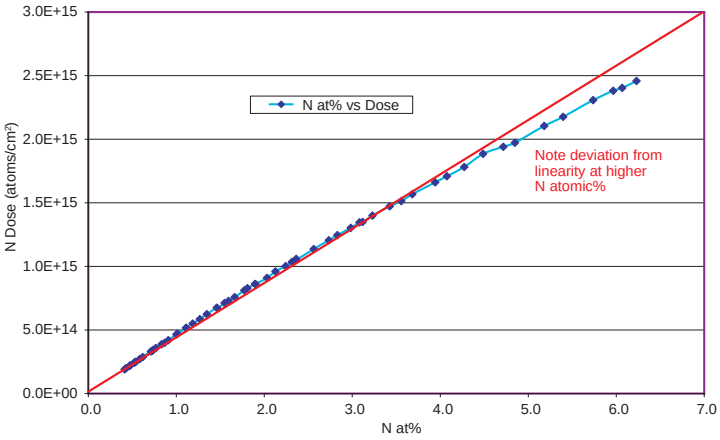

Figure 4. N Dose vs N atomic% Correlation Curve on a 200mm Wafer

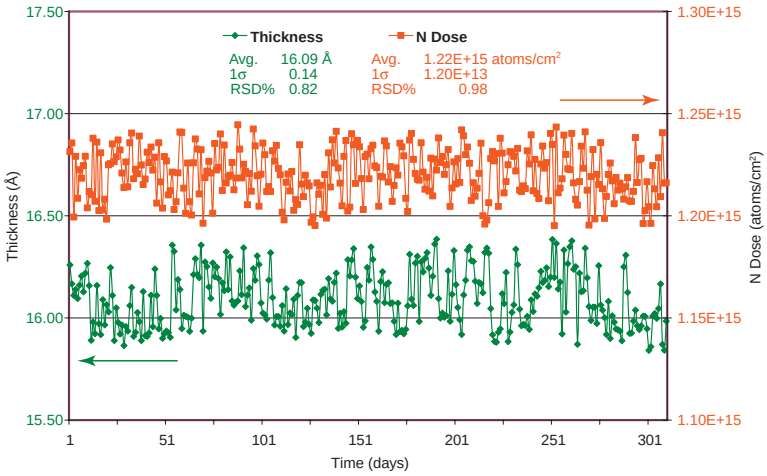

Figure 5. Long Term Repeatability XPS High Precision

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