



## 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<sup>2</sup> to  $2.5E15$  atoms/cm<sup>2</sup>. 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.

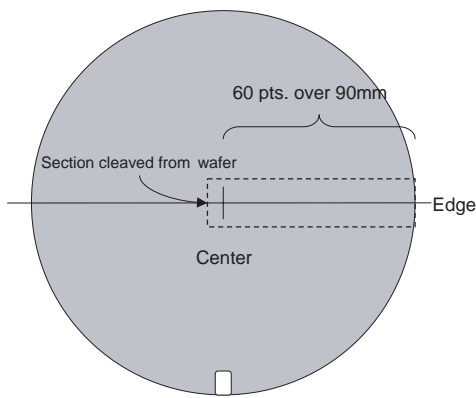


Figure 1. 200 mm SiON Wafer

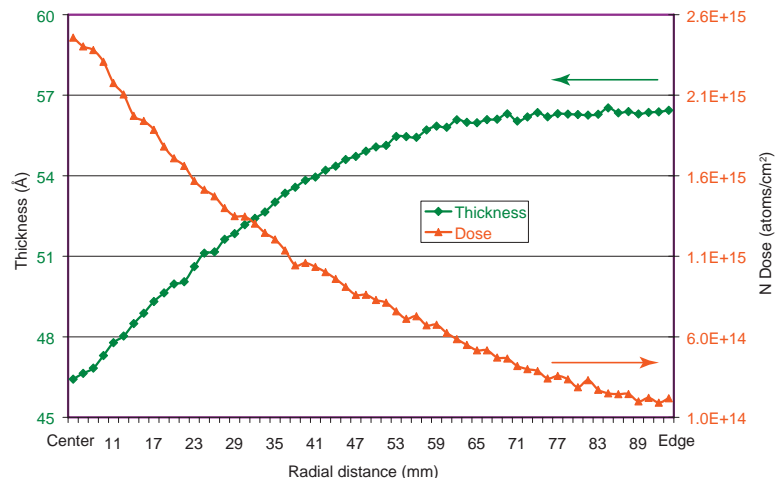
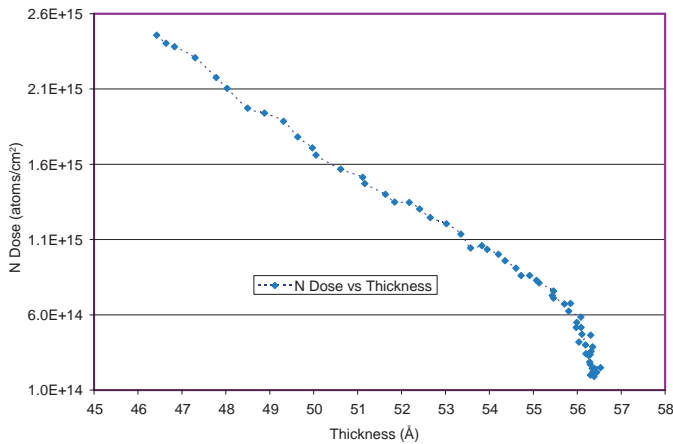
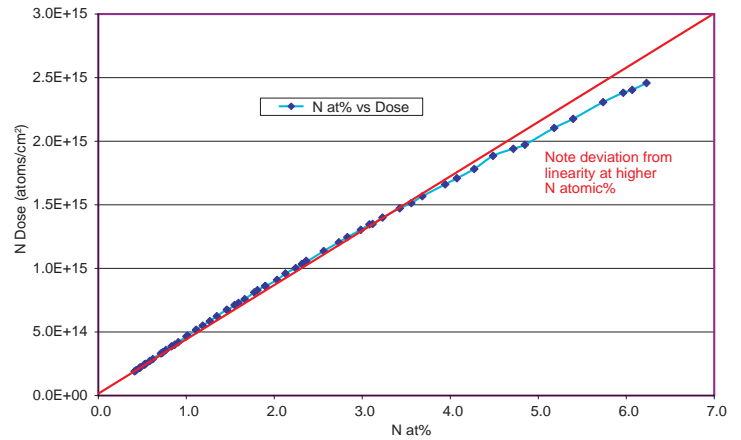


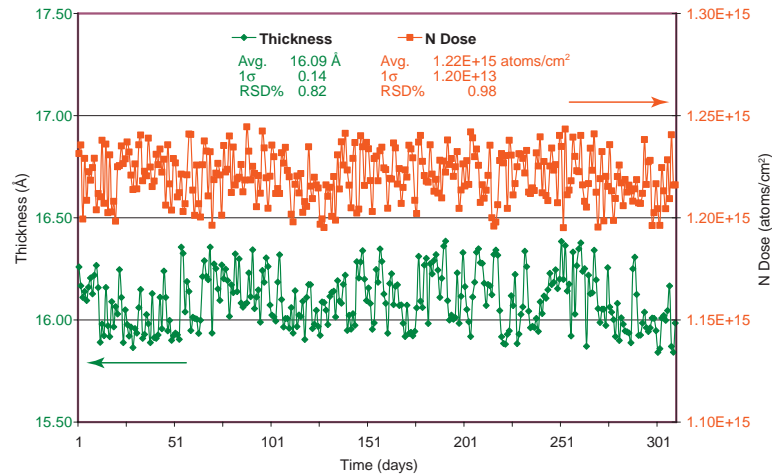
Figure 2. Thickness &amp; N Dose Uniformity 200 mm Wafer



**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**

**United States Locations**

Tempe, Arizona  
 +1 480 239 0602 info.az@eaglabs.com  
 +1 602 470 2655 fax

Sunnyvale, California  
 810 Kifer Road  
 +1 408 530 3500 info.ca@eaglabs.com  
 +1 408 530 3501 fax

1135 E Arques Avenue  
 +1 408 738 3033  
 +1 408 738 3035 fax

785 Lucerne Drive  
 +1 408 737 3892  
 +1 408 737 3916 fax

Peabody, Massachusetts  
 +1 978 278 9500 info.ma@eaglabs.com  
 +1 978 278 9501 fax

Chanhassen, Minnesota  
 +1 952 828 6411 info.mn@eaglabs.com  
 +1 952 828 6449 fax

East Windsor, New Jersey  
 +1 609 371 4800 info.nj@eaglabs.com  
 +1 609 371 5666 fax

Syracuse, New York  
 +1 315 431 9900 info.ny@eaglabs.com  
 +1 315 431 9800 fax

Raleigh, North Carolina  
 +1 919 829 7041 info.nc@eaglabs.com  
 +1 919 829 5518 fax

Round Rock, Texas  
 +1 512 671 9500 info.tx@eaglabs.com  
 +1 512 671 9501 fax

**International Locations**

Shanghai, China  
 + 86 21 6879 6088 info.cn@eaglabs.com  
 + 86 21 6879 9086 fax

Tournefeuille, France  
 + 33 5 61 73 15 29 info.fr@eaglabs.com  
 + 33 5 61 73 15 67 fax

Frankfurt, Germany  
 + 49 (0) 693053213 info.de@eaglabs.com  
 + 49 (0) 69307941 fax

Tokyo, Japan  
 + 81 3 5396 0531 info.jp@eaglabs.com  
 + 81 3 5396 1930 fax

HsinChu, Taiwan  
 + 886 3 5632303 info.tw@eaglabs.com  
 + 886 3 5632306 fax

Uxbridge, United Kingdom  
 + 44 (0) 1895 811194 info.uk@eaglabs.com  
 + 44 (0) 1895 810350 fax