OPTICAL SOLUTIONS
Spectroscopic Ellipsometers

Grazing X-Ray Reflectance

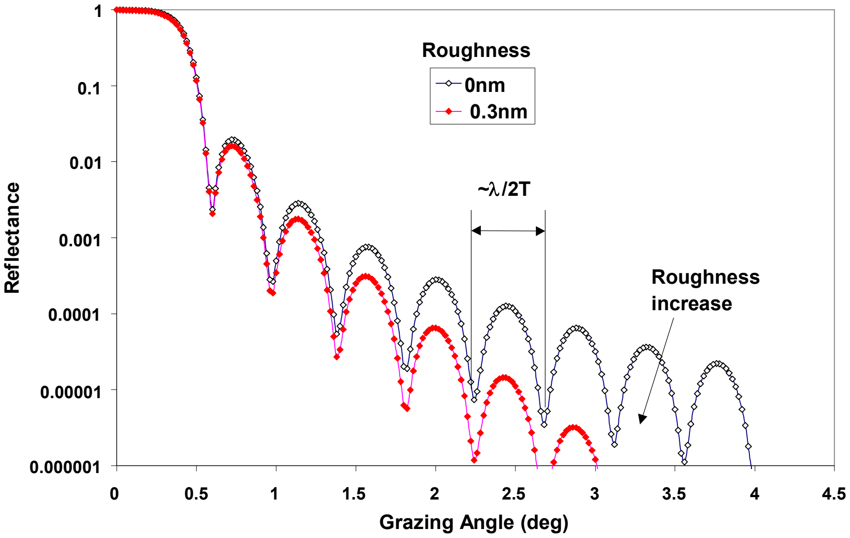
MEASUREMENT PRINCIPLE

The measurement of the specular reflectance of an x-ray beam at very grazing angle on a multiplayer structure is an extremely powerful tool to determine the individual thickness of the layers and the interface roughness.

This is due to the fact that in the x-ray wavelength range (10^{-8} to 10^{-11} m),
the index of refraction of all the materials n is given by [6]: $n(\lambda) = 1 - \delta(\lambda) - i\beta(\lambda)$

where δ and β are given by: $\delta = \lambda^2 (\frac{r_o.N}{2\pi}) \frac{\rho}{A} \sum_i x_i.f_{1i}$ $\beta = \lambda^2 (\frac{r_o.N}{2\pi}) \frac{\rho}{A} \sum_i x_i.f_{2i}$

λ is the wavelength, r_0 is the atomic radius of the electron, N the number of atoms by volume unit, ρ the density and f_1 and f_2 the real and imaginary parts of the diffusion factors of each atom. In the x-ray wavelength range, δ and β are always very small in the of 10^{-5} to 10^{-6} . The position of the interference fringes obtained versus angle for fixed wavelength give then directly the thickness of the layers without any need of model. The grazing geometry and the short wavelength used make also this kind of measurement very sensitive to roughness. The amplitude of the interference fringes depends directly on the index contrast between silicon substrate and the layer itself.



Basic Rules

Critical angle θc ⇒ medium value for index ⇒ density $\theta_c \approx \sqrt{2\delta}$
Interference fringes position ⇒ thickness
Rate of decrease of the curve ⇒ roughness

COMBINATION WITH SPECTROSCOPIC ELLIPSOMETRY

One of the main drawbacks of spectroscopic ellipsometry SE is the necessity to use optical models to extract physical parameters. For most of the situations when the optical indices of all the materials are know and when layer thickness is large enough to avoid correlation with the refractive index, SE is a very powerful method now routinely used especially in the microelectronics field. Nevertheless, in the case of very thin quasi transparent layers like for high k gate dielectrics, the thickness and optical index are completely correlated and cannot be extracted separately. Moreover, the importance of the interface and surface roughness or inter diffusion becomes critical to build an accurate structural model for these samples.