

Errors Associated With Thin Film Measurements Using XPS at a Single Angle

Key Words

- Surface Analysis
- Elastic Scattering
- Need for Angle Resolved Measurements

Background

Thermo Scientific Theta Probe and Theta 300 measure film thickness by using parallel angle resolved XPS. Other XPS tools make measurements at a single angle and calculate thickness from this one measurement. This document will show that, depending upon the electron collection geometry, significant errors can be introduced by collecting photoelectrons at only one angle. The size of the error varies with the nature of the overlayer and its thickness. These errors can be avoided if ARXPS measurements are used.

Oxide Thickness Measurements

The methods for calculating layer thickness from angle resolved XPS data are given in the application note 31014.

When measuring overlayer thickness using XPS, one has to be aware of the effect elastic scattering may have upon the results. Using Theta Probe or Theta 300, it is possible to select the angular range used to calculate the thickness of the overlayer. Figure 1 shows, for a set of silicon oxide on silicon samples, how the measured thickness depends upon the angular range used.

For the thin layers, it is possible to use a very wide angular range without introducing a significant error. For the thicker layers, however, the usable angular range is more restricted. Using Theta Probe or Theta 300, the most suitable angular range can be selected, depending upon the overlayer thickness.

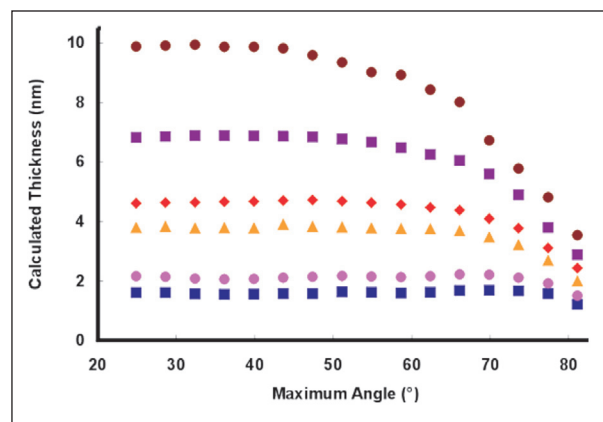


Figure 1: The calculated thickness for each of a series of SiO₂ layers on silicon as a function of the angular range used in the calculation. The x-axis shows the maximum angle used in the calculation, in all cases the minimum angle was 23°.

Single Angle Measurements

Data acquired from Theta Probe or Theta 300 can be used to simulate the data that would be obtained from instruments measuring at a fixed emission angle. This is done by summing the peak areas from the individual angles over a given angular range and then using the single angle formula for calculating the thickness.

Consider an XPS instrument which collects electrons at an angle of $45^\circ \pm 20^\circ$ from the surface normal, Figure 2.

If this geometry is used to calculate overlayer thickness then errors will arise because of elastic scattering of the electrons from the substrate. The magnitude of the error will depend upon both the nature of the overlayer and its thickness. Figure 3 shows the size of the error for layers of SiO₂, Al₂O₃ and HfO₂. If the data are collected at larger emission angles then larger errors will arise.

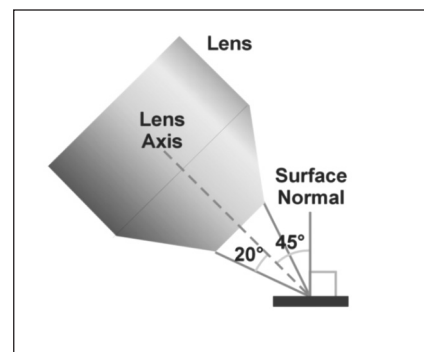


Figure 2: Spectrometer geometry considered in this document

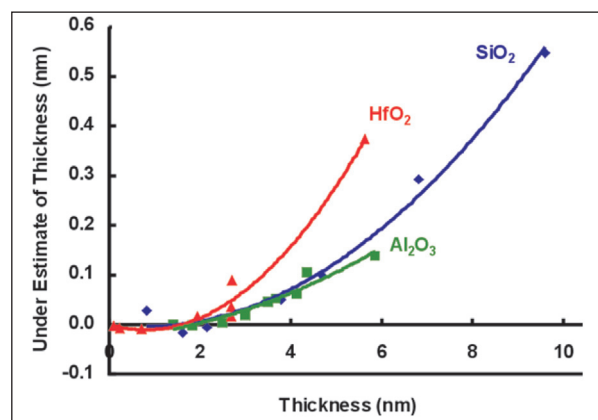


Figure 3: Under estimate of the thickness calculated from a single angle measurement having the geometry shown in Figure 2, as a function of overlayer thickness for SiO₂, Al₂O₃ and HfO₂ layers.

Conclusion

If XPS is used to measure overlayer thickness, care must be taken to avoid collecting electrons that have suffered elastic scattering within the overlayer. If this is not done then the thickness will be under estimated by an amount that depends upon:

- The geometry of the instrument
- The nature of the overlayer
- The thickness of the overlayer

By using angle resolved XPS, these errors can be avoided.

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