Application Note: 31004

Angular Linearity and Resolution on Theta Probe

Key Words

- Surface Analysis
- Angle Calibration
- Angular Linearity
- Angular Resolution

The unique feature of Thermo Scientific Theta Probe is its ability to make angle resolved XPS measurements without tilting the sample and by collecting the whole of its angular range simultaneously. The two-dimensional detector then collects the angular range in one direction and electron kinetic energy in the other direction. The purpose of this document is to report upon the linearity and the resolution of the instrument when it is used in the angle resolving mode.

1. Expected Angular Response

Electrons emitted from a uniform, homogeneous solid suffer inelastic collisions within the solid. As shown in the technical document AN31014, the intensity of the emitted electrons from a given depth is given by:

$$I = I^0 \exp(-d/\lambda\cos\theta)$$

Where I^0 is the intensity from an infinitely thick substrate, d is the depth and θ is the angle of emission. To get to the total emission from the material the above expression must be integrated with respect to d from zero to infinity. On doing this it will be found that:

$$I_{total} \propto \cos\theta$$

The angular distribution of electron intensity should therefore have a cosine dependency.

2. Experimental

For speed and convenience all these data were obtained using electrons from a flood gun. A beam of 500 eV electrons was directed at a smooth silver sample and the elastically scattered electrons were measured in the analyzer.

With the Theta Probe operating in its angle resolving mode, the sample was placed in the analysis position and the angular response recorded. The detector was set to collect data in 96 angular channels. This is shown in Figure 1 and compared this with a cosine curve. The cosine curve has been normalized to the signal value at the smallest angle.

Clearly there is very good agreement between the two curves. This indicates qualitatively that the angle resolving mode is operating correctly. However, a more quantitative method is needed to establish the accuracy, linearity and angular resolution from the instrument.

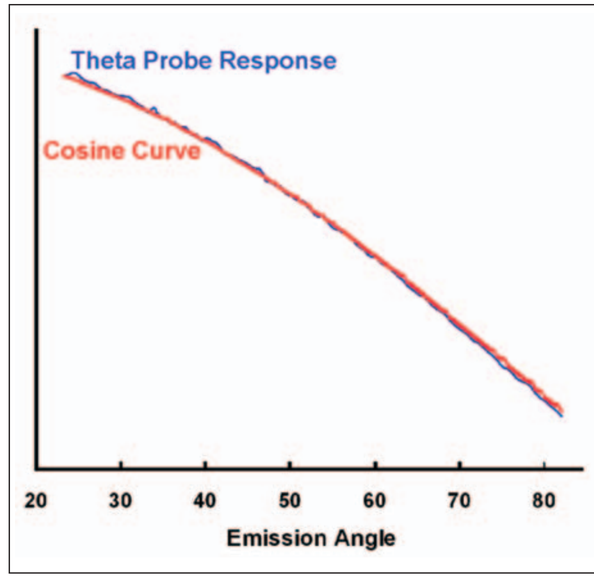

Figure 1: Comparison of the angular response from Theta Probe with a cosine curve

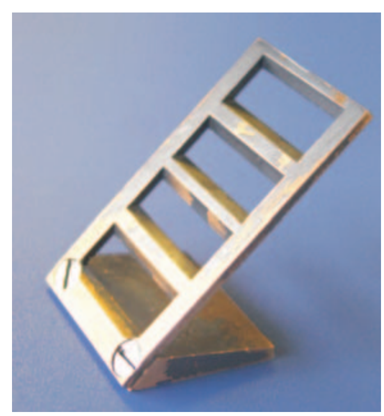

Figure 2: The calibration ladder

3. The Calibration "Ladder"

This device was designed to allow precisely-defined angular ranges of electrons to enter the Theta Probe lens. This has the appearance of a ladder and its photograph is shown in Figure 2.

The ladder is manufactured in such a way that, when it is placed against the lens of the instrument, there are four angular ranges within which electrons can pass into the lens and three ranges within which electrons are prevented from entering the lens. The total angular range is 60° and these seven angular ranges are all equal to 8.57° (60°/7). The operation of the ladder is illustrated in Figure 3.

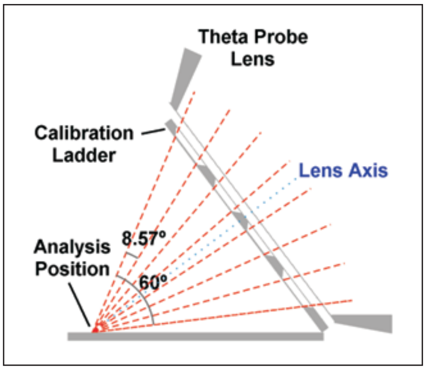

Figure 3: The angular ranges defined by the calibration ladder

4. Angular Linearity

Another set of angular data, similar to that shown in Figure 1, was collected with the ladder placed in front of the lens. As expected, there were four angular regions within which signal was able to reach the lens and three regions within which the signal was blocked. The results are shown in Figure 4.

By measuring the angle at which the signal reaches 50% of its maximum value for each step change in signal and plotting this against the angle defined by the ladder, the linearity of the angular detector can be determined. The calibration graph is shown in Figure 5 along with a linear regression line through the experimental points.

The accuracy and linearity of the angular measurements can be seen to be excellent.

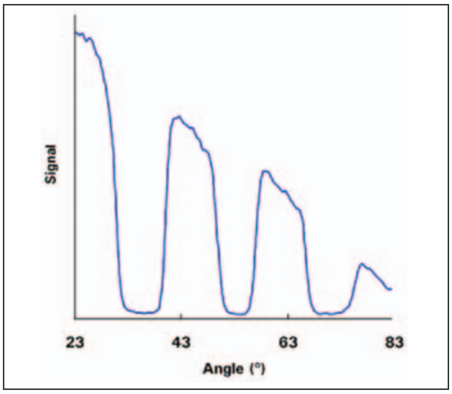

Figure 4: Angular data collected by Theta Probe through the calibration ladder

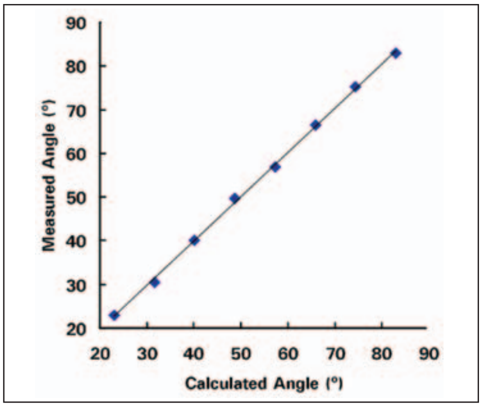

Figure 5: Correlation of the angles measured from the Theta Probe with the angles calculated from the geometry of the ladder

5. Angular Resolution

To determine the angular resolution obtained from Theta Probe each of the step changes in Figure 5 must be examined more closely. For the purpose of this document the angular resolution will be defined as the angular range over which the signal changes from 20% to 80% of its maximum value at each step. Hence from Figure 4 we can make six measurements of the angular resolution, the data is plotted in Figure 6.

From Figure 6 it can be seen that the angular resolution is always less than 1.6°, the mean value over the full angular range is less than 1.3°. Since the detection system was set to collect data from 96 angular channels the resolution might be expected to be 60°/96 = 0.625°. It is therefore evident that the resolution is determined by the electron optical system rather than the resolution of the two dimensional detector.

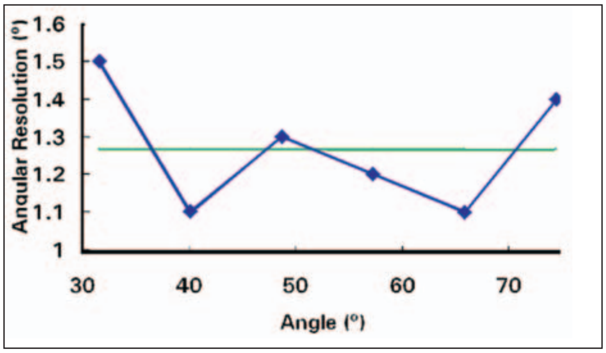

Figure 6: The measured angle resolution of Theta Probe as a function of collection angle. The horizontal line on this graph shows the mean value for the resolution of < 1.3°

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AN31004_E 05/08M