Application Note: 31003

Operation of the Angle Resolving Lens on Theta Probe

Key Words

- Surface Analysis
- Angle Resolving Lens Mode
- Electron Trajectories

In its angle resolving mode, Thermo Scientific Theta Probe is operated such that the electron kinetic energy is dispersed in one direction on its 2-dimensional detector and angular distribution in the other direction. Figure 1 shows an image of the detector when Theta Probe is being operated in this mode.

It is the purpose of this document to describe in outline how this is achieved.

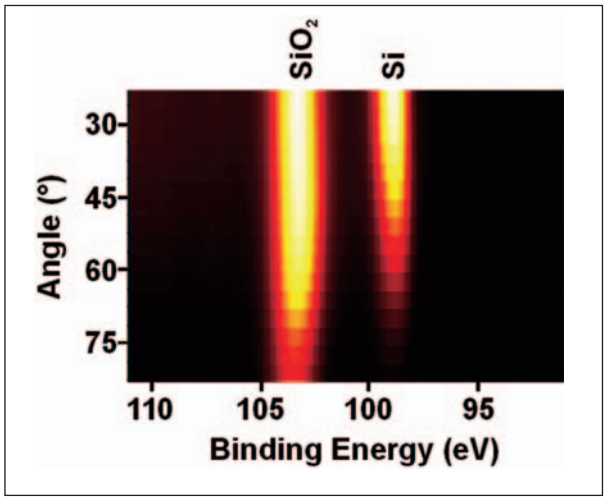

Figure 1: An image of the output from Thermo Scientific Theta Probe detector. This shows angular dispersion in one direction and energy dispersion in the other direction. The sample being analyzed in this case is a silicon wafer with a thin layer of oxide on its surface.

1. Optical Analogy

A convenient method for illustrating the way in which Theta Probe lens operates is by means of an optical analogy.

1.1 Analyzer Energy Dispersion Plane

Figure 2 shows the optical analogy for a two-lens system. Lens combinations of this type are frequently used as XPS transfer optics. Photoelectrons emitted from the sample are focused by Lens 1 and form an image at Image Plane 1. A second lens, Lens 2, forms a photoelectron image of the sample at the analyzer input slit. Electrons reach the slit plane at a point which is dependent upon their initial position at the sample. In this mode of operation the analyzer slit plane is a second image plane.

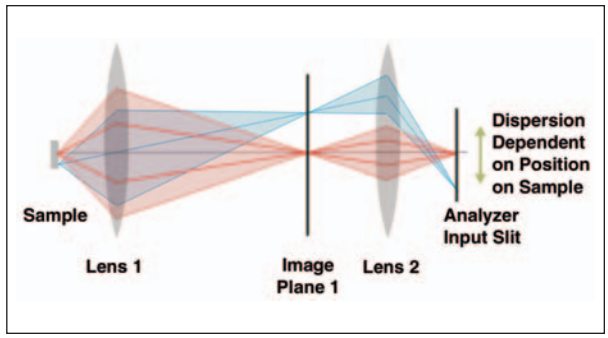

Figure 2: The optical analogy for the energy dispersive plane of the transfer lens in the in Theta Probe.

1.2 Analyzer Angular Dispersion Plane

To obtain angular dispersion at the analyzer slit plane, the focal length of Lens 2 must be changed. Figure 3 shows the requirement.

The focal length of Lens 2 needs to be set such that it is equal to the distance between Image Plane 1 and Lens 2. As can be seen from Figure 3, this means that the position at which the electrons reach the slit plane is independent of their initial position on the sample but is dependent upon the angle at which they leave the sample surface, i.e. a diffraction image is formed at the analyzer slit plane.

This is the means by which the angular distribution of the electrons as they leave the sample surface is converted to spatial distribution at the input to the Analyzer in the angular dispersive plane.

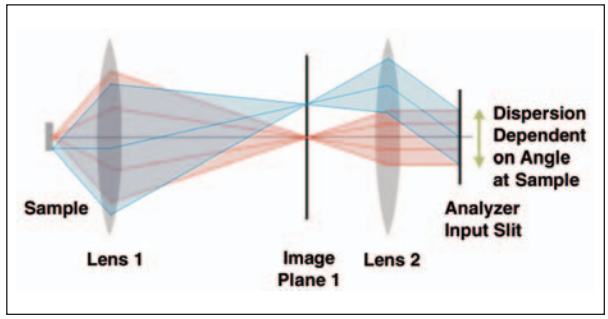

Figure 3: The optical analogy for the angle dispersive plane of the transfer lens in Theta Probe.

Thermo SCIENTIFIC

The hemispherical analyzer on Theta Probe is a focusing element as well as an energy filter and so the angle and position of the electrons as they enter the analyzer is mirrored at the exit plane.

2. Practical Implementation

When Theta Probe is operated in its angle resolving mode, the electron optical system is similar to Figure 2 in the energy dispersive plane and similar to Figure 3 in the non-dispersive plane.

For optimum performance, Lens 1 in Theta Probe is designed to have two important features.

1. It must collect photoelectrons over a wide angular range to allow angular measurements to be made from near normal to near grazing angles. This also maximizes sensitivity.
2. It must be operated at high magnification to keep the angle of the electrons into Lens 2 as small as possible.

For these reasons Lens 1 has a large diameter and a maximum collection angle of 60°. It is designed to operate with a magnification of 4 so that the angular range of electrons into Lens 2 is ± 7.5°.

Lens 2 must be capable of providing a different focal length in each plane. This is accomplished using a quadrupole lens, illustrated in Figure 4.

The quadrupole lens in Theta Probe is similar to a conventional three-element cylindrical lens but the central element is divided longitudinally into four quadrants. If the same potential is applied to all of these quadrants then the lens operates in the same way as a conventional three-element lens and the focal length in the xz plane is the same as that in the yz plane.

In Theta Probe opposite pairs of the central lens elements are connected together and a different potential can be applied to each pair. This has the result that the focal length in the xz plane is different from the focal length in the yz plane. This allows the required combination of conditions illustrated in Figures 2 and 3. With a real image forming at the analyzer's input slit in the energy dispersive direction and a diffraction image formed in the other direction.

Taking into account the focusing properties of the analyzer, the electrons are then dispersed onto the two-dimensional detector such that in one direction the position on the detector is determined by the kinetic energy of the electrons and in the other direction the position on the detector is determined by the angle at which the electrons left the sample surface in the angular dispersive plane.

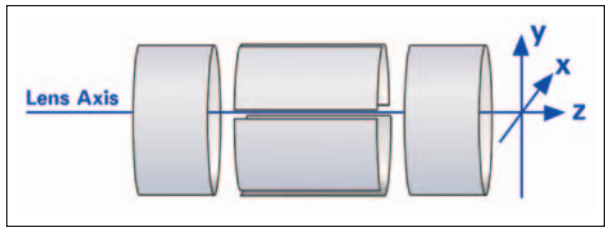

Figure 4: Schematic diagram of a quadrupole lens

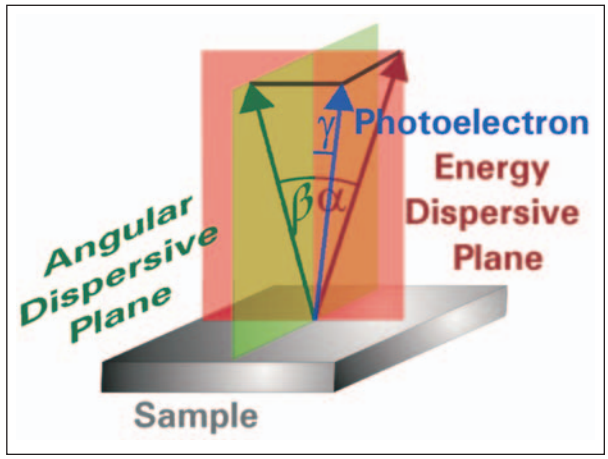

Figure 5: Components of the emission angle in the energy dispersive and angular dispersive planes

3. Compound Angles

A photoelectron emitted at an angle γ with respect to the surface normal, see Figure 5, is likely to have components of its direction in both the energy dispersive plane (α in Figure 5) and the angular dispersive plane (β). This electron will reach the detector at position which depends upon its total kinetic energy and the angle β. The position of the detected electron is totally independent of a.

The maximum value for β is 30° and for α is about 2.5° when Theta Probe is operated in its angle resolving mode.

4. Electron Trajectories

Figures 6 to 8 illustrate the trajectories of electrons through the lens and analyzer when Theta Probe is operated in its angle resolving mode.

Figure 6 shows the trajectory of the electrons in the energy dispersive plane of the analyzer. Figure 7 shows the trajectories in the angle resolving direction while Figure 8 shows the combination of these two sets of rays.

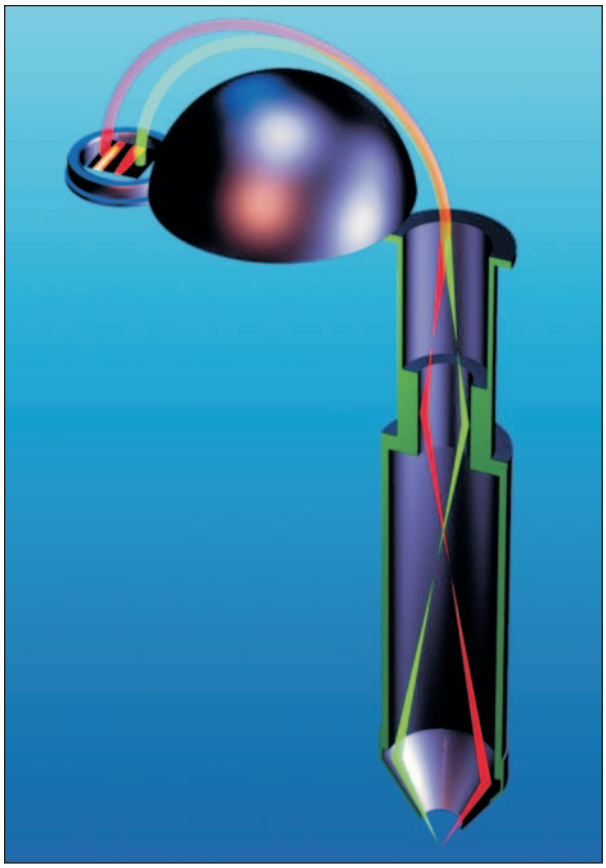

Figure 6: Trajectory of electrons through Theta Probe showing the energy dispersion. The electron trajectories shown are for electrons of differing energies but with the same input angle in the angular dispersive plane.

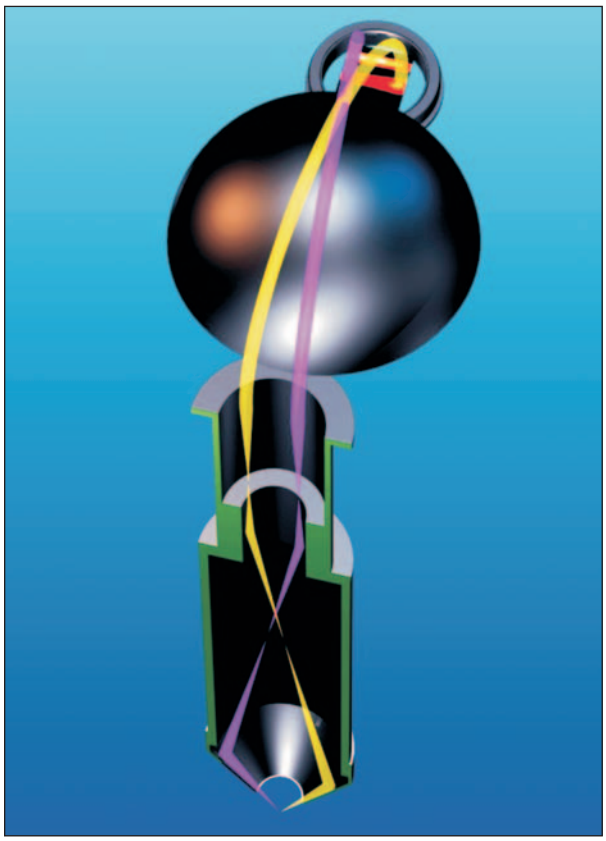

Figure 7: Trajectory of electrons through Theta Probe showing the angular dispersion. The electron trajectories shown are for electrons of the same energy but with differing input angles in the angular dispersive plane.

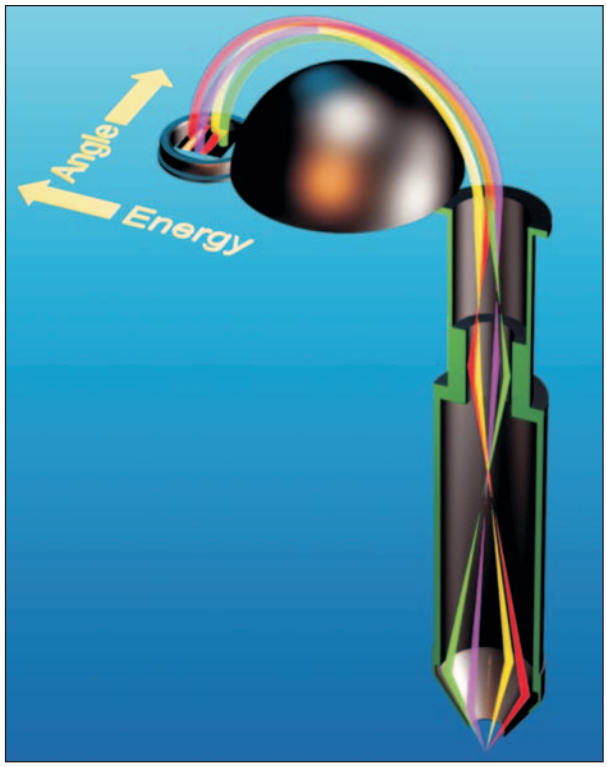

Figure 8: Trajectory of electrons through Theta Probe showing both the energy dispersion and the angular dispersion.

In addition to these offices, Thermo Fisher Scientific maintains a network of representative organizations throughout the world.

Africa
+43 1 333 5034 127

Australia
+61 2 8844 9500

Austria
+43 1 333 50340

Belgium
+32 2 482 30 30

Canada
+1 800 530 8447

China
+86 10 8419 3588

Denmark
+45 70 23 62 60

Europe-Other
+43 1 333 5034 127

France
+33 1 60 92 48 00

Germany
+49 6103 408 1014

India
+91 22 6742 9434

Italy
+39 02 950 591

Japan
+81 45 453 9100

Latin America
+1 608 276 5659

Middle East
+43 1 333 5034 127

Netherlands
+31 76 579 55 55

South Africa
+27 11 570 1840

Spain
+34 914 845 965

Sweden/Norway/ Finland
+46 8 556 468 00

Switzerland
+41 61 48784 00

UK
+44 1442 233555

USA
+1 800 532 4752

www.thermo.com

VG Systems Ltd. Trading as Thermo Fisher Scientific, East Grinstead, UK is ISO Certified.

AN31003_E 06/08M