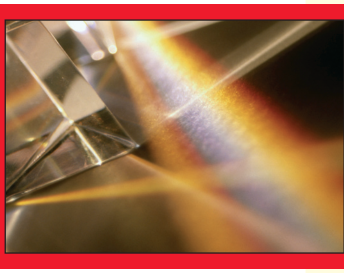
TECHNICAL NOTE



Spherical Mirror Analyser

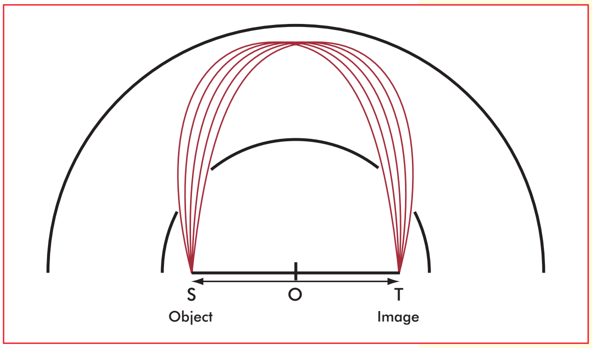


Figure 1: Object and image points of SMA

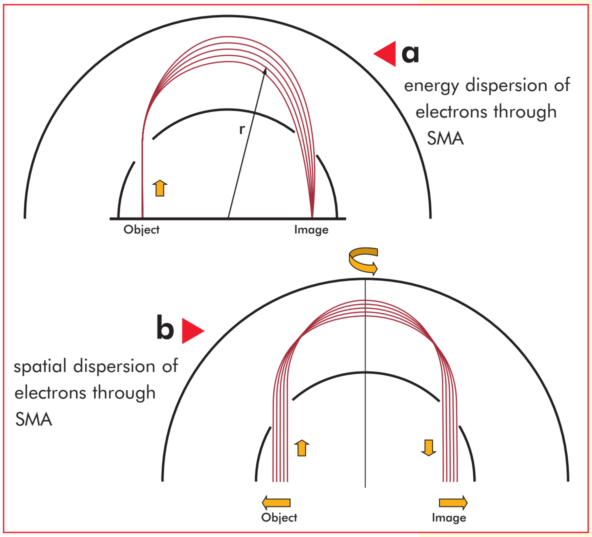


Figure 2: Energy dispersion and spatial distribution of photoelectrons through SMA

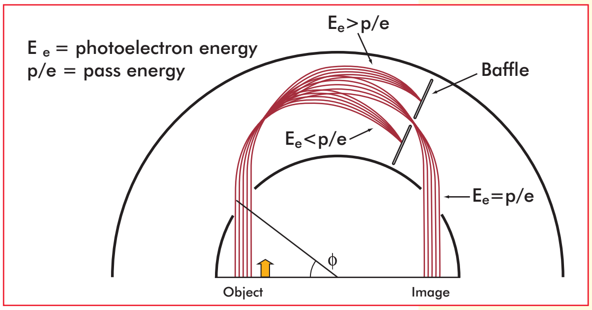


Figure 3: Electron trajectories through SMA

Overview

A fundamental requirement of an imaging analyser is the ability to transmit spatially distributed photoelectrons from the input lens system with minimum distortion whilst maintaining high spatial and energy resolution over a large field of view. The spherical mirror analyser (SMA), first introduced by *Sar-El*[1], achieves this performance through several key properties. As is shown in Figure 1, electrons are delivered by the lens system to the entrance slit of the analyser S. The symmetrical nature of the analyser means that all electrons converge at the exit point T with perfect focussing and complete lack of spherical aberration. Therefore an image formed at the entrance point of the analyser will be transmitted to the exit of the analyser with unit magnification and zero distortion; the first fundamental criterion for an imaging analyser.

The perfect imaging properties of the SMA are evident. However, to function as an imaging analyser for XPS, the system must also be able to perform energy selective analysis. Figure 2a shows the energy dispersion of photoelectrons with energy spread $E_0 \pm 4\%$ originating from a point source at the entrance to the SMA. The energy dispersion vanishes at the image plane indicating that imaging quality is not degraded by energy spread. Figure 2b shows how the spatial distribution of a parallel beam of electrons entering the SMA has two regions with little dependence upon radial position of the entrance position. Again unit magnification is displayed and symmetry about the axis shows how a 2-dimensional image is transmitted.

Figure 3 shows the electron trajectories through the SMA of a parallel beam of electrons with energy $E_0 \pm 4\%$. The point where the energy dispersion is at a maximum is coincident with the second minimum in the spatial distribution. By inserting a baffle into the SMA at this position, electrons with energy equal to that of the pass energy are transmitted, whilst those with energy greater than the pass energy are not transmitted. Crucially this has no effect on spatial resolution of the image formed at the exit plane of the analyser, therefore it is apparent that the properties of the SMA form an ideal imaging XPS analyser.

A 2-dimensional detector positioned at the image plane of the analyser will detect energy resolved 2-dimensional XPS images. The analyser initially incorporated a multi-channel plate detector with a phosphor scintillation disk and CCD camera detection arrangement but latterly this detection arrangement has been replaced with a pulse counting delay-line detection (DLD) system offering direct pulse counting of parallel images.

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Parallel XPS Images

The SMA has been successfully incorporated into imaging XPS spectrometers, as described by *Page*[2], following the schematic arrangement shown in Figure 4. The outer hemisphere of the classical hemispherical sector analyser (HSA) acts as the inner hemisphere of the SMA. In XPS imaging mode electrons pass through the HSA to be energy analysed by the SMA.

The SMA runs in fixed analyser transmission mode (FAT) so that energy resolution, ΔE, is constant over the binding energy range, E. This is a fundamental requirement of an XPS analyser as a constant energy resolution throughout the binding energy range is essential to acquire meaningful chemical state images of the analysed sample.

By changing the properties of the electrostatic and magnetic lenses, images with variable fields of view (FOV) can be acquired ranging from 2mm to 100μm, as shown in Figure 5. The ultimate spatial resolution readily obtainable from the parallel imaging analyser is < 3μm as shown in Figure 6 where an XPS image of the Au 4f core level electrons from a Au grid shows < 3μm resolution using the 80:20% edge definition.

Although spatial resolution is important, energy resolution through the analyser is key to forming chemical state XPS images. Figure 7 shows a Ag $3d_{5/2}$ spectrum acquired by scanning the SMA energy through the Ag 3d energy range. Spectra were then recreated from the image data to show an equivalent energy resolution to the HSA in spectroscopy mode.

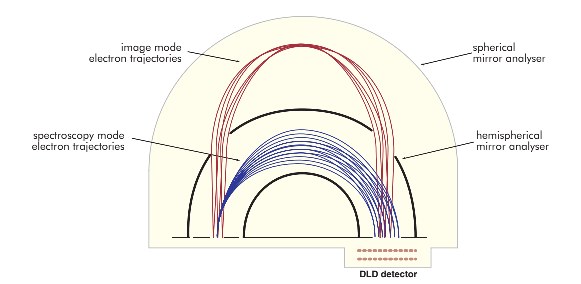

Figure 4: *Integration of SMA with HSA for XPS imaging and spectroscopy*

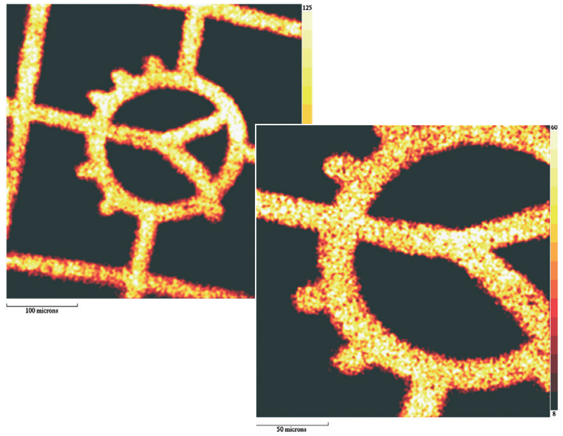

Figure 5: *Parallel XPS images from Au grid*

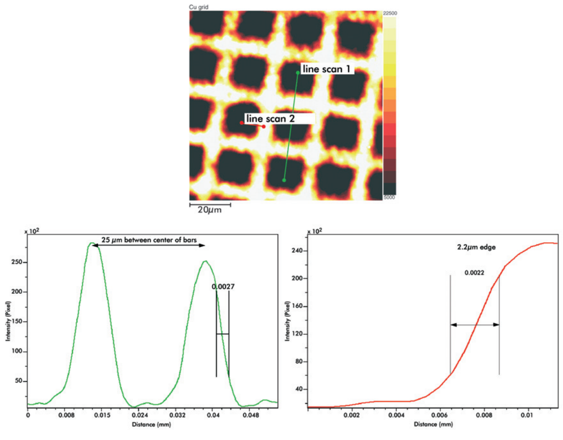

Figure 6: *Resolution <3μm from an Au grid*

Summary

It is clear that the SMA has unique properties allowing collection of both the highest spatial resolution and energy resolution XPS images. When combined with a pulse counting delay-line detector it provides the unique ability to obtain quantitative parallel XPS images. The spherical mirror analyser is a key component of AXIS Ultra and AXIS Nova imaging photoelectron spectrometers.

References

1 Sar-El HZ, *Nuclear Instrum. Method,* **42** 71 (1966)

2 Page SC, Charged Particle Energy Analysers *European Patent No* EP 0 458 498 (1991)

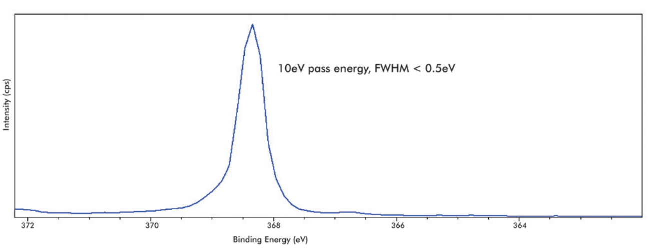

Figure 7: *Ag $3d_{5/2}$ spectrum reconstructed from images*

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