

Surface chemical analysis — Auger electron spectroscopy and X-ray photoelectron spectroscopy — Determination of lateral resolution

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National foreword

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Surface chemical analysis — Auger electron spectroscopy and X-ray photoelectron spectroscopy — Determination of lateral resolution

*Analyse chimique des surfaces — Spectroscopie d'électrons Auger et
spectroscopie de photoélectrons de rayons X — Détermination de la
résolution latérale*



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Contents

Page

Foreword.....	iv
Introduction	v
1 Scope	1
2 Normative references	1
3 Terms, definitions, symbols and abbreviated terms.....	1
3.1 Terms and definitions.....	1
3.2 Symbols and abbreviated terms	2
4 General information.....	2
4.1 Background information	2
4.2 Measurement of lateral resolution in AES and XPS	3
4.3 Dependence of lateral resolution on scan direction	3
4.4 Methods for the measurement of lateral resolution in AES and XPS	4
5 Measurement of lateral resolution with the straight-edge method	4
5.1 Introduction	4
5.2 Variants of the straight-edge method	4
5.3 Selection of the straight-edge specimen.....	5
5.4 Mounting the straight-edge specimen.....	5
5.5 Cleaning the straight-edge specimen.....	5
5.6 Operating the instrument.....	6
5.7 Data collection	6
5.8 Data analysis	8
6 Measurement of lateral resolution with the grid method.....	10
6.1 Introduction	10
6.2 Selection of the grid specimen.....	10
6.3 Mounting the grid specimen	10
6.4 Cleaning the grid specimen	10
6.5 Operating the instrument.....	11
6.6 Data collection	11
6.7 Data analysis	13
7 Measurement of lateral resolution with the gold-island method	13
7.1 Introduction	13
7.2 Selection of the gold-island specimen	13
7.3 Mounting the gold-island specimen	13
7.4 Cleaning the gold-island specimen	14
7.5 Operating the instrument.....	14
7.6 Data collection	14
7.7 Data analysis	16
Annex A (informative) Determination of lateral resolution of an XPS instrument with a focused X-ray spot	17
Annex B (informative) Determination of lateral resolution from a secondary-electron line scan	19
Annex C (informative) Determination of lateral resolution from Auger-electron line scans	21
Bibliography	24

Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 18516 was prepared by Technical Committee ISO/TC 201, *Surface chemical analysis*, Subcommittee SC 5, *Auger electron spectroscopy*.

Introduction

Auger electron spectroscopy (AES) and X-ray photoelectron spectroscopy (XPS) are surface-analytical techniques that are used to generate chemical maps and line scans of surfaces, and to provide spectroscopic analyses from defined areas. These techniques can have lateral resolutions as good as 10 nm for AES and can cover areas as large as many square centimetres in XPS. Different instruments generate images or define spectroscopic areas with different lateral resolutions, so inter-comparisons of image quality are poorly defined without clearly defined methods and terms with which to express the results. Different settings of an instrument may also change the lateral resolution. An analyst needs to have a suitable method to measure the lateral resolution of an instrument for any given settings. In this way, analysts can obtain the optimum lateral resolution from a given instrument, appropriate to the analytical requirements, in a consistent and clear way. The resolution actually achieved in subsequent analyses will approach these values in XPS but, generally, the resolution in AES may be degraded by the effects of electron backscattering. The ability of the analyst to realise these resolutions in an effective way will, of course, also depend on the quality of the signal levels obtained.

This International Standard describes three methods for the determination of lateral resolution in AES and XPS. The method chosen for use depends on the expected value of the lateral resolution. Annexes A, B and C provide illustrative examples of the measurement of lateral resolution.

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1 Scope

This International Standard describes three methods for measuring the lateral resolution achievable in Auger electron spectrometers and X-ray photoelectron spectrometers under defined settings. The straight-edge method is suitable for instruments where the lateral resolution is expected to be larger than 1 μm . The grid method is suitable if the lateral resolution is expected to be less than 1 μm but more than 20 nm. The gold-island method is suitable for instruments where the lateral resolution is expected to be smaller than 50 nm.

Annexes A, B and C provide illustrative examples of the measurement of lateral resolution.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 18115:2001, *Surface chemical analysis — Vocabulary*

3 Terms, definitions, symbols and abbreviated terms

3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 18115 apply. The definition of lateral resolution is repeated here for convenience.

3.1.1

resolution, lateral

distance measured either in the plane of the sample surface or in a plane at right angles to the axis of the image-forming optics over which changes in composition can be separately established with confidence

NOTE 1 The choice of plane should be stated.

NOTE 2 In practice, the lateral resolution may be realized as either (i) the FWHM of the intensity distribution from a very small emitting point on the sample, or (ii) the distance between the 12 % and 88 % intensity points in a line scan across a part of the sample containing a well-defined step function for the signal relating to the property being resolved. These two values are equivalent for a Gaussian intensity distribution. For other distributions, other parameters may be more appropriately chosen. Often, for a step function, the distance between the 20 % and 80 % intensity points or the 16 % and 84 % intensity points in the line scan are used. The latter pair gives the two-sigma width for a Gaussian resolution function.

ISO 18115:2001, definition 5.255

NOTE 3 For the purposes of this International Standard, measurement in the plane of the sample is preferred.

3.2 Symbols and abbreviated terms

AES	Auger electron spectroscopy
d	diameter of an electron beam (of axial symmetry) incident on a sample surface
FWHM	full width at half maximum
XPS	X-ray photoelectron spectroscopy
x	parameter needed for the determination of lateral resolution; the measurement of lateral resolution begins when the signal intensity is x % of the maximum intensity and ends when the intensity is $(100 - x)$ % of the maximum. In the case of $\delta r(50)$, x is 25
θ	angle of incidence of an electron beam or an X-ray beam on a sample surface measured with respect to the surface normal

4 General information

4.1 Background information

A common need in AES and XPS is the measurement of composition as a function of position on the sample surface. Typically, an analyst wishes to determine the local surface composition of some identified region of interest. This region of interest could be a feature on a semiconductor wafer (such as an unwanted defect particle or contamination stain), a corrosion pit, a fibre or an exposed surface of a composite material. With growing industrial fabrication of devices with dimensions on the micrometre and nanometre scales, particularly in the semiconductor industry and for emerging nanotechnology applications, there is an increasing need to characterize materials using tools with lateral resolutions that are smaller than those of the features of interest. It is generally necessary in these applications to be able to determine that devices have been fabricated as intended (quality control), to evaluate new or current fabrication methods (process development and process control), and to identify failure mechanisms (failure analysis) of a device during its service life or after exposure to different ambient conditions. The lateral resolution is an important parameter in the application of characterization techniques such as AES and XPS for the surface characterization of materials containing features with micrometre and nanometre dimensions.

It is clearly desirable that the lateral resolution of the technique be smaller than the lateral dimensions of the feature of interest in order that the feature can be readily imaged. The feature of interest in an AES instrument might typically be initially detected in a scanning electron micrograph. The primary electron beam could then be positioned on the feature and an Auger spectrum recorded. In XPS instruments, the feature of interest must generally be detected from an image or a line scan in which a particular signal (often the intensity of a selected photoelectron peak) is displayed as a function of position on the sample surface.

In practice, the detectability of a feature in AES and XPS measurements depends not only on the lateral resolution but also the difference in signal intensities for measurements made on and off the possible feature (materials contrast) and the observation time (through the statistical variations in the signal intensities). The detectability of a feature thus depends on an instrumental characteristic (the lateral resolution), the particular constituents of the sample, and the measurement time. Reliable detection of a feature will also depend on instrumental stability (particularly the stability of the incident electron beam current in AES, the X-ray flux in XPS, and the positional stability of the sample stage with respect to the electron or X-ray beam) and the chemical stability of the sample during the time needed for acquisition of AES or XPS data.

Many authors have described and discussed the lateral resolution (often referred to as spatial resolution) of AES and XPS instruments. Useful information can be found in Reference [1] for AES and in Reference [2] for XPS. ISO/TR 19319 gives guidance on the determination of lateral resolution and related parameters in AES and XPS [3].

4.2 Measurement of lateral resolution in AES and XPS

The lateral resolution for AES and XPS measurements typically depends on either the characteristics of the incident radiation or the characteristics of the lens-analyser-detector system used in the spectrometer. In the former case, the lateral resolution will depend mainly on the cross-sectional dimensions (e.g. the beam diameter) of the incident radiation (electron beam in AES or the X-ray beam in XPS) at the sample surface, and will improve as the beam diameter decreases. In the latter case, the lateral resolution will depend mainly on the electron-optical design of the lens-analyser-detector system together with any apertures that may be positioned in the electron-optical path. This is the situation

- a) when the spectrometer is used for lens-defined small-area XPS,
- b) when images are produced by scanning the acceptance area of the lens, or
- c) when the spectrometer produces parallel images by projecting photoelectrons of the appropriate energy through the lens-analyser system to the detector.

The methods described in Clause 5 involve measurements of the intensity of a selected AES or XPS spectral feature while a sufficiently sharp chemical gradient (a chemical edge) on the sample is translated through the analysis position (defined by the incident beam) or the analysis position is translated across a chemical edge. The measured lateral resolution will depend on the instrumental design (i.e. the beam diameter or the electron-optical design of the spectrometer), the intrinsic sharpness of the chemical edge used for the measurements and, for AES, the magnitude and width of the Auger signal excited by back-scattered electrons ^[1].

4.3 Dependence of lateral resolution on scan direction

The measured lateral resolution can depend upon the direction in which the translation of the sample with respect to the incident beam or the spectrometer is made. This variation can arise in any of the following three situations:

- a) if an X-ray or electron beam of circular cross section (i.e. the beam has axial symmetry) is incident on the sample at a non-zero angle relative to the surface normal; the beam-intensity profile on the sample will then be an ellipse, as shown in Figure 1 for the case of an incident electron beam;
- b) if the lateral resolution is defined by the analyser or lens, and the sample normal is not parallel with the entrance axis of the analyser; or
- c) if the incident beam is astigmatic.

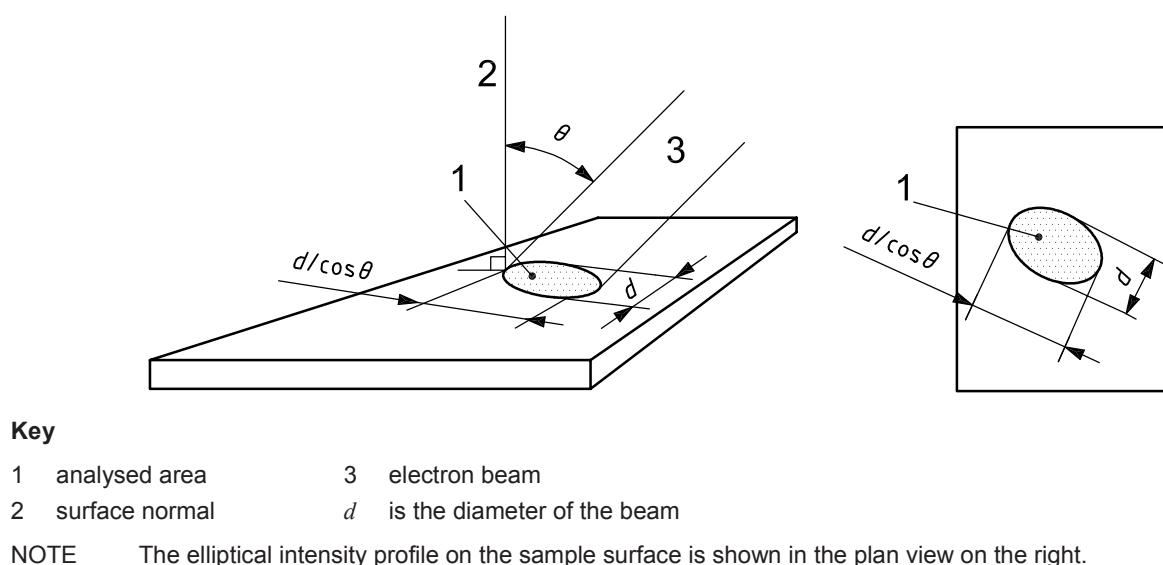


Figure 1 — Example of an electron beam striking the sample at an angle θ relative to the surface normal