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Surface chemical analysis – Fundamental approaches to determination of lateral resolution in beam-based methods

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National foreword

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TECHNICAL REPORT

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Surface chemical analysis – Fundamental approaches to determination of lateral resolution and sharpness in beam-based methods

Analyse chimique des surfaces — Approche fondamentale pour la détermination de la résolution latérale et de la netteté par des méthodes à base de faisceau

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Foreword

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In exceptional circumstances, when a technical committee has collected data of a different kind from that which is normally published as an International Standard ("state of the art", for example), it may decide by a simple majority vote of its participating members to publish a Technical Report. A Technical Report is entirely informative in nature and does not have to be reviewed until the data it provides are considered to be no longer valid or useful.

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ISO/TR 19319 was prepared by Technical Committee ISO/TC 201, *Surface chemical analysis*, Subcommittee SC 2, *General procedures*.

This second edition cancels and replaces the first edition (ISO/TR 19319:2003), which has been technically revised.

Introduction

Surface-analytical techniques such as SIMS, AES and XPS enable imaging of surfaces. The most relevant parameter of element or chemical maps and line scans is the lateral resolution, also called image resolution.[1)] Therefore well defined and accurate procedures for the determination of lateral resolution are required. Those procedures together with appropriate test specimen are basic preconditions for comparability of results obtained by imaging surface-analytical methods and performance tests of instruments as well. This Technical Report is intended to serve as a basis for the development of International Standards.

Nowadays there is some confusion in the community in the understanding of the term "lateral resolution". Definitions originating from different fields of application and different communities of users can be found in the literature. Unfortunately they are inconsistent in many cases. As a result, values of "lateral resolution" published by manufacturers and users having been derived by using different definitions and/or determined by different procedures cannot be compared to each other. It is the intention of this Technical Report to basically describe different approaches for the characterization of lateral resolution including their interrelations.

The term resolution was introduced with respect to the performance of microscopes by Ernst Abbe.[1] Later on it was applied to spectroscopy by Lord Rayleigh.[2] It is based on the diffraction theory of light and the original definition of lateral resolution as "the minimum spacing at which two features of the image can be recognised as distinct and separate" is in common use in the light and electron microscopy communities as documented in the standard ISO 22493:2008.[3]

However, in the surface analysis community a very different approach, the "knife edge method", is the most popular one for the determination of lateral resolution. This method is based on evaluation of an image or of a line scan over a straight edge. Here lateral resolution is characterized by parameters describing the steepness of the edge spread function ESF. The standard "ISO 18516:2006 Surface Chemical Analysis – Auger electron spectroscopy and X-ray photoelectron spectroscopy – Determination of lateral resolution"[4] is limited to this approach. But the ESF and corresponding rise parameters $D_{x-(1-x)}$ are more related to image sharpness than to lateral resolution which refers to two separated features.

The reason why the original meaning of resolution is not commonly implemented in the common practice in surface analysis is the lack of suitable test specimens having the required features in the sub-µm range. However, recently a new type of test specimen was developed featuring a series of flat square-wave gratings characterized by chemical contrast and different periods.[5,6] Such test specimens may enable an implementation of the original definition of lateral resolution into practical approaches in surface chemical analysis.

Having solved the problem of availability of appropriate test specimens another problem has to be solved: The establishment of a criterion for whether two features are separated or not. The Rayleigh criterion[2] was developed for diffraction optics and its application in imaging surface analysis is not straightforward. The Sparrow criterion[7] defines a resolution threshold exclusively by the existence of a minimum between two maxima. Actually, for practical imaging in surface analysis, noise is a relevant feature especially at the limit of resolution. Therefore the Sparrow criterion will fail to solve the problem. The solution is to develop a resolution criterion relying on the detection of a minimum between two features but additionally considering noise effects.

The lateral resolution of imaging systems is strongly related to a number of functions describing the formation of images:

— the modulation transfer function,

— the contrast transfer function,

— the point spread function,

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1) The term "image resolution" is used in the microscopy community whereas in the surface analysis community the term "lateral resolution" is common practice to distinguish it from "depth resolution".

— the line spread function and

— and the edge spread function.

Those functions may be utilized to describe the performance of optical instruments and instruments used for imaging in surface analysis as well. In particular the contrast transfer function has been used successfully for the benefit of the determination of lateral resolution of imaging instruments in surface analysis.

Section 4 of this report describes the basics of procedures for the analysis of images of stripe patterns, narrow stripes and step transitions. A comparison of all procedures related to lateral resolution and sharpness is given in 4.1.7.

Section 5 of the report describes physical factors affecting lateral resolution, analysis area and sample area viewed by the analyser in Auger electron spectroscopy and X-ray photoelectron spectroscopy. Section 6 of the report gives guidance on the determination of sample area viewed by the analyser in applications of Auger electron spectroscopy and X-ray photoelectron spectroscopy.

TECHNICAL REPORT ISO/TR 19319:2013(E)

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1 Scope

This Technical Report describes:

a) Functions and their relevance to lateral resolution:

   1) Point spread function (PSF) — see 4.1.1

   2) Line spread function (LSF) — see 4.1.2

   3) Edge spread function (ESF) — see 4.1.3

   4) Modulation transfer function (MTF) — see 4.1.4

   5) Contrast transfer function (CTF) — see 4.1.5.

b) Experimental methods for the determination of lateral resolution and parameters related to lateral resolution:

   1) Imaging of a narrow stripe — see 4.2

   2) Imaging of a sharp edge — see 4.3

   3) Imaging of square-wave gratings — see 4.4.

c) Physical factors affecting lateral resolution, analysis area and sample area viewed by the analyser in Auger electron spectroscopy and X-ray photoelectron spectroscopy — see Clauses 5 and 6.

2 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

2.1
analysis area
<sample> two-dimensional region of a sample surface measured in the plane of that surface from which the entire analytical signal or a specified percentage of that signal is detected

[SOURCE: ISO 18115:2010, definition 5.8]

2.2
contrast transfer function
CTF
ratio of the image contrast to the object contrast of a square-wave pattern as a function of spatial frequency

Note 1 to entry: In this document the contrast transfer function CTF has been used also with an abscissa expressed in terms of w_{LSF}/P and is called the generalized contrast transfer function in those cases (cf. 4.4.3.2). w_{LSF} is the full width at half maximum of the line spread function LSF

Note 2 to entry: In transmission electron microscopy and other phase sensitive methods the term contrast transfer function is used with a different meaning considering amplitude as well as phase information.