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Microbeam analysis — Analytical electron microscopy — Vocabulary

Analyse par microfaisceaux — Microscopie électronique analytique — Vocabulaire

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2. www.iso.org/directives

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The committee responsible for this document is ISO/TC 202, *Microbeam analysis*, Subcommittee SC 1, *Terminology*.

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Introduction

Analytical electron microscopy (AEM) is a technique used to qualitatively determine and quantitatively measure the elemental composition and examine the electronic state of the small volume of solid material observed by transmission electron microscopy (TEM) and scanning transmission electron microscopy (STEM). AEM is based on the physical mechanism of electron-stimulated X-ray spectrometry and electron energy loss spectrometry (EELS). AEM also provides structural information from small regions by microdiffraction while still possessing the capability of high-resolution imaging.[9]

As a major sub-field of microbeam analysis (MBA), AEM is widely applied in diverse business sectors (high-technology industries, basic industries, metallurgy and geology, biology and medicine, environmental protection, trade, etc.) and has a wide business environment for standardization.

The standardization of terminology in a technical field is one of the basic prerequisites for the development of standards on other aspects of that field.

This International Standard is relevant to the international scientific and engineering communities that require an AEM vocabulary that contains consistent definitions of terms, as they are used in the practice of MBA combined with TEM and STEM.

This International Standard is one developed in a package of standards on scanning electron microscopy (SEM; ISO 22493), electron probe X-ray microanalysis (EPMA; ISO 23833), energy-dispersive X-ray spectrometry (EDS; ISO 22309), etc., which have been either already developed or are to be developed by ISO/TC 202, *Microbeam analysis*, to completely cover the field of MBA.

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Microbeam analysis — Analytical electron microscopy — Vocabulary

0 Scope

This International Standard defines terms used in the practice of AEM. It covers both general and specific concepts classified according to their hierarchy in a systematic order.

This International Standard is applicable to all standardization documents relevant to the practice of AEM. In addition, some parts of this International Standard are applicable to those documents relevant to the practice of related fields (e.g. TEM, STEM, SEM, EPMA, EDX) for the definition of those terms common to them.

NOTE See also the ISO online browsing platform (OBP): https://www.iso.org/obp/ui/

1 Abbreviated terms

AEM analytical electron microscope/microscopy

CBED convergent beam electron diffraction

CCD charge-coupled device

CRT cathode ray tube

EDS energy-dispersive X-ray spectrometer/spectroscopy

EDX energy-dispersive X-ray spectrometer/spectroscopy

EELS electron energy loss spectrometer/spectroscopy

EPMA electron probe microanalysis

FFT fast Fourier transform

FIB focused ion beam

FWHM full width at half maximum

HAADF high-angle annular dark field

HREM high-resolution transmission electron microscope/microscopy

LAADF low-angle annular dark field

MBA microbeam analysis

SE secondary electron

SEM scanning electron microscopy

STEM scanning transmission electron microscope/microscopy

TEM transmission electron microscope/microscopy

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2 Definitions of terms used in the physical basis of AEM

2.1
electron optics
science that deals with the trajectory of electrons as they pass through electrostatic and/or electromagnetic fields

[SOURCE: ISO 22493, modified]

2.1.1
electron source
device that generates electrons necessary for forming an electron beam in an electron optical system

2.1.1.1
energy spread
diversity of energy of electrons in the incident beam

[SOURCE: ISO 22493, modified]

2.1.1.2
effective source size
effective dimension of the electron source typically measured at the beam crossover

[SOURCE: ISO 22493, modified]

2.1.2
electron emission
ejection of electrons from the surface of a material under certain excitation conditions

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[SOURCE: ISO 22493:2008, 3.1.2]

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2.1.2.1
thermionic emission
electron emission which relies on the use of high temperature to enable electrons in the cathode to overcome the work function energy barrier and escape into the vacuum assisted by the application of an external electrostatic field

[SOURCE: ISO 22493, modified]

2.1.2.2
field emission
electron emission caused by the strong electric field on and near the surface of the material

[SOURCE: ISO 22493, modified]

2.1.2.2.1
cold field emission
field emission in which the emission process relies purely on the applied electric field to extract electrons from the cathode operating at ambient temperature

[SOURCE: ISO 22493, modified]

2.1.2.2.2
thermal field emission
field emission in which the emission process relies on both the elevated temperature of the cathode tip and an applied electric field of high voltage

[SOURCE: ISO 22493, modified]

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2.1.3
electron lens
basic component of an electron optical system, using an electrostatic and/or electromagnetic field to change the trajectories of the electrons passing through it

2.1.3.1
electrostatic lens
electron lens employing an electrostatic field formed by a specific configuration of electrodes

2.1.3.2
electromagnetic lens
electron lens employing an electromagnetic field formed by a specific configuration of electromagnetic coils (or permanent magnets) and pole pieces

[SOURCE: ISO 22493:2008, 3.1.3.2]

2.1.4
focusing
converging an electron beam to a minimum diameter using an electron lens

[SOURCE: ISO 22493, modified]

2.1.5
demagnification
numerical value by which the diameter of the electron beam exiting a lens is reduced in comparison to the diameter of the electron beam entering the lens

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[SOURCE: ISO 22493:2008, 3.1.5]

2.2
electron scattering
electron deflection with or without the loss of kinetic energy as a result of collision(s) with target atom(s) or electron(s)

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[SOURCE: ISO 22493 and ISO 23833, modified]

2.2.1
elastic scattering
electron scattering in which energy and momentum are conserved in the collision system

[SOURCE: ISO 22493:2008, 3.2.1]

2.2.1.1
zero loss
unscattered and elastically scattered electrons (with only minimal loss of energy due to phonon excitation), giving rise to an intensity peak or the position of which defines zero in the electron energy loss spectrum

2.2.2
inelastic scattering
electron scattering in which energy and/or momentum are not conserved in the collision system

Note 1 to entry: For inelastic scattering, the electron trajectory is modified by plasmon loss, core loss, and other multiple scatterings

[SOURCE: ISO 22493, modified]

2.2.2.1
thermal diffuse scattering
electron scattering which is caused by electron-phonon scattering due to thermal vibration of the lattice

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2.2.2.2
plasmon loss
type of energy loss in EELS in which the incident electron is affected by the collective oscillations of free electrons in the specimen and loses kinetic energy as a result

2.2.2.3
inner-shell ionization
excitation of an electron bound in an inner-shell (nonvalence) orbital to an unbound state in the continuum above the Fermi level

2.2.2.4
core loss
energy loss of an electron in the beam caused by excitation of an inner-shell electron

2.2.3
scattering cross-section
hypothetical area normal to the incident radiation that would geometrically intercept the total amount of radiation actually scattered by a scattering atom

Note 1 to entry: Scattering cross-section is usually expressed only as area (m^2).

[SOURCE: ISO 22493:2008, 3.2.3]

2.3
Bloch wave
wave function of an electron in a periodic crystal potential, which is written as the product of a plane wave envelope function and a periodic function that has the same periodicity as the crystal potential

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2.3.1
anomalous absorption
absorption of Bloch wave in a crystalline material when the wave is symmetric and forms its antinodes at the nuclei

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2.3.2
anomalous transmission
transmission of Bloch wave in a crystalline material when the wave is antisymmetric and forms its nodes at the nuclei

2.4
coherence
wave property exhibited by electron beams in which two waves share the same frequency and are in phase

Note 1 to entry: Phase shifts between two coherent beams result in interference and generate diffraction patterns.

2.5
TEM
microscopy technique or microscope where images of an ultrathin specimen are obtained by an electron beam that is transmitted through it

2.5.1
HREM
method for obtaining lattice and crystal structure images by interfering with a transmitted electron wave and diffracted electron waves using an electromagnetic lens with a small spherical aberration

2.5.2
STEM
transmission electron microscopy technique which rasters the focused electron beam over the specimen

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2.5.3
HAADF-STEM
imaging mode in a scanning transmission electron microscope in which images are formed by collecting very high-angle, incoherently scattered electrons with an annular dark-field detector

2.5.4
LAADF-STEM
imaging mode in a scanning transmission electron microscope in which images are formed by collecting low-angle elastic and inelastic scattering electrons with an annular dark-field detector

2.5.5
ABF-STEM
imaging technique of acquiring a bright-field scanning transmission electron microscope image with an annular detector

2.6
electron holography
application of holography techniques to electron waves in which the coherent beam is split into at least two beams by using an electron biprism

2.6.1
electron prism
device which splits the coherent electron beam into several beams in order to obtain an interferogram or hologram

2.7
Lorentz electron microscopy
method for observing magnetic domain structures by use of the transmission electron microscope

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2.8
phase-contrast electron microscopy
TEM technique in which small phase shifts in the transmitted beam resulting from interactions with the specimen are converted into amplitude or contrast changes in the image

2.9
electron tomography
reconstruction technique of a three-dimensional structure by the computer-assisted image processing of a series of projected images obtained by continuously tilting the specimen

3 Definitions of terms used in AEM instrumentation

3.1
electron gun
component that produces an electron beam with a well-defined kinetic energy

[SOURCE: ISO 22493:2008, 4.1]

3.1.1
Schottky emission
thermionic electron emission that takes place under an electric field that enhances the emission by lowering the surface barrier

[SOURCE: ISO 22493, modified]

3.1.2
field emission gun
electron gun employing field emissions sources, such as cold field electron emission or Schottky emission

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