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Microbeam analysis — Scanning electron microscopy — Vocabulary

Analyse par microfaisceaux — Microscopie électronique à balayage — 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 (see www.iso.org/directives).

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For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the WTO principles in the Technical Barriers to Trade (TBT) see the following URL: Foreword - Supplementary information

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

This second edition cancels and replaces the first edition (ISO 22493:2008), of which it constitutes a minor revision.

Introduction

The scanning electron microscopy (SEM) technique is used to observe and characterize the surface morphology and structure of solid materials, such as metal alloys, ceramics, glasses, minerals, polymers, powders, etc., on a spatial scale of micrometer down to nanometer laterally. In addition, three-dimensional structure can be generated by using a combination of focused ion beam and scanning-electron-based analysis techniques. The SEM technique is based on the physical mechanism of electron optics, electron scattering and secondary electron emission.

As a major sub-field of microbeam analysis (MBA), the SEM technique is widely applied in diverse sectors (high-tech industries, basic industries, metallurgy and geology, biology and medicine, environmental protection, trade, etc.) and has a strong business base that needs standardization.

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

This International Standard is relevant to the need for an SEM terminology that contains consistent definitions of terms as they are used in the practice of scanning electron microscopy by the international scientific and engineering communities that employ the technique. This International Standard is the second one developed in a package of standards on electron probe microanalysis (EPMA), scanning electron microscopy (SEM), analytical electron microscopy (AEM), energy-dispersive X-ray spectroscopy (EDS), etc., developed or to be developed by Technical Committee ISO/TC 202, *Microbeam analysis*, Subcommittee SC 1, *Terminology*, to cover the complete field of MBA.

Microbeam analysis — Scanning electron microscopy — Vocabulary

1 Scope

This International Standard defines terms used in the practice of scanning electron microscopy (SEM). It covers both general and specific concepts, classified according to their hierarchy in a systematic order, with those terms that have already been defined in ISO 23833 also included, where appropriate.

This International Standard is applicable to all standardization documents relevant to the practice of SEM. In addition, some clauses of this International Standard are applicable to documents relevant to related fields (e.g. EPMA, AEM, EDS) for the definition of terms which are relevant to such fields.

2 Abbreviated terms

AEM	analytical electron microscope/microscopy
BSE (BE)	backscattered electron
CPSEM	controlled pressure scanning electron microscope/microscopy
CRT	cathode ray tube
EBIC	electron beam induced current
EBSD	electron backscatter/backscattering diffraction
EDS	energy-dispersive spectrometer/spectrometry
EPMA	electron probe microanalyser/analysis
ESEM	environmental scanning electron microscope/microscopy
FWHM	full width at half maximum
SE	secondary electron
SEM	scanning electron microscope/microscopy
VPSEM	variable-pressure scanning electron microscope/microscopy

3 Terms and definitions used in the physical basis of SEM

3.1
electron optics
science that deals with the passage of electrons through electrostatic and/or electromagnetic fields

3.1.1
electron source
device that generates electrons necessary for forming an electron beam in the electron optical system

3.1.1.1
energy spread
diversity of energy of electrons

3.1.1.2
effective source size
effective dimension of the electron source

3.1.2
electron emission
ejection of electrons from the surface of a material under given excitation conditions

3.1.2.1
field emission
electron emission caused by the strong electric field on and near the surface of a material

3.1.2.1.1
cold field emission
field emission in which the emission process relies purely on the high-strength electrostatic field in a high-vacuum environment with the cathode operating at ambient temperature

3.1.2.1.2
thermal field emission
Schottky 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 in a high-vacuum environment

3.1.2.2
thermionic emission
electron emission that 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

3.1.3
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

3.1.3.1
electrostatic lens
electron lens employing an electrostatic field formed by a specific configuration of electrodes

3.1.3.2
electromagnetic lens
electron lens employing an electromagnetic field formed by a specific configuration of electromagnetic coil (or permanent magnet) and pole piece

3.1.4
focusing
aiming the electrons onto a particular point using an electron lens

3.1.5
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

3.2
electron scattering
electron deflection and/or its kinetic energy loss as a result of collision(s) with target atom(s) or electron(s)

3.2.1
elastic scattering
electron scattering in which energy and momentum are conserved in the collision system

3.2.1.1
backscattering
electron scattering in which the incident electrons scatter backwards and out of the target after suffering deflections

3.2.2
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 a small angle, generally less than 0,01 rad.

3.2.3
scattering cross-section
hypothetical area normal to the incident radiation that would geometrically intercept the total amount of radiation actually scattered by a scattering particle

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

3.2.4
mean free path
mean distance between electron scattering events in any material

3.2.5
Bethe range
estimate of the total distance an electron can travel in any material (including vacuum and a target), obtained by integrating the Bethe stopping power equation over the energy range from the incident value to a low threshold value (e.g. 1 keV)

Note 1 to entry: This assumes that the electron loses energy continuously in the material rather than as occurs in practice where energy is lost in discrete scattering events.

3.3
backscattered electron
BSE
electron ejected from the entrance surface of the specimen by the backscattering process

Note 1 to entry: By convention, an electron ejected with an energy greater than 50 eV may be considered as a backscattered electron.

3.3.1
backscattering coefficient
BSE yield
η
ratio of the total number of backscattered electrons to the total number of incident electrons

3.3.2
BSE angular distribution
distribution of backscattered electrons as a function of their emitting angle relative to the specimen surface normal

3.3.3
BSE atomic number dependence
variation of backscattering coefficient as a function of the atomic number of the specimen

3.3.4
BSE beam energy dependence
variation of backscattering coefficient with beam energy

3.3.5
BSE depth distribution
distribution describing the locations of the electrons at their maximum depth in the specimen before subsequently being backscattered from the specimen surface

3.3.6
BSE energy distribution
distribution of backscattered electrons as a function of their emitting energy

3.3.7
BSE escape depth
maximum depth in a specimen from which a backscattered electron may emerge

3.3.8
BSE lateral spatial distribution
two-dimensional distribution of backscattered electrons escaping as a function of the distance from the beam impact point to the lateral position of escape

3.4
secondary electron
electron emitted from a specimen as a result of bombardment by the primary electrons

Note 1 to entry: By convention, an electron with energy less than 50 eV is considered as a secondary electron.

3.4.1
SE yield
secondary electron coefficient
total number of secondary electrons per incident electron

3.4.2
SE angular distribution
distribution of secondary electrons as a function of their emitting angle relative to the surface normal

3.4.3
SE energy distribution
distribution of secondary electrons as a function of their emitting energy

3.4.4
SE escape depth
maximum depth under a surface from which secondary electrons are emitted

3.4.5
SE tilt dependence
effect on secondary electrons of the specimen tilt which accompanies a change in incident beam angle

3.4.6
SE_1 (SE_I)
secondary electrons that are generated by the incident beam electrons within the specimen

3.4.7
SE_2 (SE_{II})
secondary electrons that are generated by the backscattered electrons within the specimen

3.4.8
SE_3 (SE_{III})
secondary electrons that are generated by the electrons backscattered from the specimen somewhere remotely beyond the point of incidence

3.4.9
SE_4 (SE_{IV})
secondary electrons that are generated by the incident beam electrons within the electron optical column

3.5
electron penetration
physical process of forwards travelling by an energetic incident beam electron before losing all its energy within the target (specimen)

3.5.1
electron range
measure of the straight-line penetration distance of electrons in a solid

3.5.2
interaction volume
volume below the incident electron beam impact area at the specimen surface, within which the beam electrons travel and experience elastic and inelastic scattering

3.5.3
information volume
volume of the specimen from which the measured signal originates

3.5.4
penetration depth
depth to which an incident electron travels in a target

3.5.5
Monte Carlo simulation
calculation that simulates stochastic physical processes (here: the electron diffusion in the solid state) and thus can be used to model the electron probe - sample interaction and SEM image formation

3.6
electron channelling
physical process occurring in crystalline materials of greater electron penetration along directions of low atomic density

3.7
electron diffraction
physical process of particularly strong scattering of the incident electron beam at certain angles relative to the atomic planes in a crystal

3.7.1
electron backscattering diffraction
EBSD
diffracting process that arises between the backscattered electrons and the atomic planes of a specimen illuminated by the incident electron beam

4 Terms and definitions used in SEM instrumentation

4.1
electron gun
component that produces an electron beam with a well-defined kinetic energy

4.1.1
field emission gun
electron gun employing field emission

4.1.1.1
cold field emission gun
electron gun employing cold field emission

4.1.1.1.1
extracting electrode
electrode applying the electrostatic potential to extract electrons from the electron source

4.1.1.1.2
flashing
short-time heating process usually applied to a cold field emission gun to clean the surface of the electron source tip

4.1.1.2
thermal field emission gun
electron gun employing thermal field emission

4.1.2
thermionic emission gun
electron gun employing thermionic emission

4.1.2.1
tungsten hairpin gun
thermionic emission gun employing a tungsten hairpin filament as its cathode

4.1.2.2
LaB_6 gun
thermionic emission gun employing a heated block of single-crystal LaB_6 as its cathode

4.1.2.3
anode
one of the electrodes making up the electron gun, to which a high positive voltage relative to the cathode is applied to accelerate the emitted electrons from the cathode

4.1.2.4
cathode
one of the electrodes making up the electron gun, which is at a negative electric potential relative to the anode

4.1.2.5
Wehnelt cylinder
cap-shaped electrode, placed between anode and cathode in the electron gun, which acts to focus electrons inside the gun and to control the amount of electron emission

4.1.3
brightness
β
current per unit area at the focus position and per unit solid angle in the beam

Note 1 to entry: Brightness is given by the equation

$$\beta = 4I/(\pi^2 d^2 \alpha^2)$$

where

I is the current, in amperes;

d is the beam diameter, in metres, at the focus position;

α is the beam half-angle, in radians.

4.1.4
reduced brightness

β'

brightness (beam current density) normalized to the beam acceleration voltage

Note 1 to entry: Reduced brightness is given by the equation

$\beta' = \beta / V$

where

β is the measured brightness;

V is the electron beam acceleration voltage.

4.1.5
emission current

total electron current emitted from the cathode

4.1.6
saturation

specific cathode heating condition at which a change in the cathode heating current will result in only a small change in the electron beam current, which is close to its maximum

4.2
electron lens system

combination of various electron lenses to obtain specific electron optics functions

4.2.1
aberration

divergence from ideal properties of an electron optical element, e.g. lens imperfections like spherical aberration, chromatic aberration, diffraction, that degrade the lens optical performance

4.2.1.1
chromatic aberration

lens defect that arises because electrons from the same point but of slightly different energies will be focused at different positions in the image plane

4.2.1.2
spherical aberration

lens defect which arises because electrons in trajectories further away from the optic axis are bent more strongly by the lens magnetic field than those near the axis

4.2.2
aperture

diaphragm with an axial opening that defines the transmission of the lens

4.2.2.1
aperture angle

half of the angle subtended by the diameter of the aperture at the point of beam focus

4.2.2.2
aperture diffraction

defect that arises at very small aperture diameters because the wave nature of electrons gives rise to a diffraction pattern instead of a point in the Gaussian image plane

4.2.2.3
objective aperture

aperture that restricts the cross-sectional area of the electron beam incident on the specimen

4.2.2.4

virtual objective aperture

beam-limiting aperture located between the last condenser and the objective lens

4.2.3

astigmatism

phenomenon in which electrons emerging from a point object are focused to form two separate focal lines at 90° to one another rather than a point focus as formed by a perfectly cylindrical lens

Note 1 to entry: It arises from the lens asymmetrical magnetic field caused by machining errors, inhomogeneities in the pole pieces, asymmetry in the lens windings and imperfect apertures.

4.2.3.1

stigmator

device that applies weak supplementary magnetic fields to correct astigmatism

4.2.4

condenser lens

electron optical device used to converge or diverge transmitted electrons

Note 1 to entry: The principal function of the condenser is to set the beam current and control its three-dimensional shape.

4.2.5

objective lens

lens in a microscope closest to the specimen

Note 1 to entry: The principal function of the objective lens is to focus the final probe.

4.2.5.1

conical lens

objective lens in the shape of a cone pointing towards the specimen

4.2.5.2

immersion lens

electron lens in which the object lies deep within the electric field so that the lens field varies rapidly in its vicinity

4.2.5.3

snorkel lens

objective lens of asymmetric single-pole configuration with the ability to accommodate large specimens, with low aberrations and with flexibility for through-lens electron detection and imaging

4.3

scanning system

device incorporated in the electron optical system for achieving time-controlled one- or two-dimensional movement of the electron probe on the specimen surface and synchronized signal collection to generate line scans or images

4.3.1

analogue scanning system

scanning system with an analogue circuit as its scanning signal source, in which the electron probe is moved continuously, with a rapid scan along the *x*-axis (the line scan) and a slower scan at right angles along the *y*-axis (the frame scan), so that a good approximation to an orthogonal scan is produced

4.3.2

digital scanning system

scanning system, with a digital circuit as its scanning signal source, in which the electron probe is moved discretely from a point being addressed to a particular location (x, y) in a matrix, remains there for a fixed time (the dwell time) and is then moved to the next data collection point

4.3.3
double deflection
action of deflecting the electron beam at first off-axis and then to cross the optical axis again at the final (beam defining) aperture

4.3.4
dwell time
time during which the electron probe stays in a particular location in digital scanning operation

4.4
specimen chamber
compartment just next to the objective lens where the specimen stage with specimen is accommodated and manipulated

4.4.1
charge balance
condition at which the number of incident electrons impinging on the specimen surface equals the number of electrons (secondary, backscattered, etc.) leaving the specimen

4.4.2
differential pumping
pumping method designed to achieve and maintain the different vacuum values for chambers connected by diaphragms which prevent the exchange of large amounts of gas

4.4.3
gas path length
average distance electrons pass through gas to reach the specimen

4.4.4
gas amplification
effect of multiple ionization events leading to secondary electron cascade due to electron-gas interaction under an applied electric field leading to a signal gain

4.4.5
CPSEM
controlled pressure SEM
variable pressure SEM
VPSEM
environmental SEM
ESEM
controlled pressure SEM which can operate with a pressure in the specimen chamber from 1 Pa up to 5 000 Pa so that direct secondary emission is no longer detectable and images are obtained with the detection of electrons by *gas amplification* (4.4.4), *environmental SE detector* (4.6.2.6), ions, photoemission or using other signals such as BSE or absorbed current

Note 1 to entry: This type of SEM can be also used with a normal vacuum in the chamber.

4.5
specimen
sampled material designated to be examined or analysed

4.5.1
specimen stage
device, located in the specimen chamber, which enables the specimen to be appropriately mounted, manipulated and held in place

Note 1 to entry: It usually allows for some of the five degrees of freedom in motion, i.e. *x*-*y*-*z* displacements, tilting and rotating.

4.5.2
working distance
distance between the lower surface of the pole piece of the objective lens and the specimen surface

Note 1 to entry: In the past, this distance was defined as the distance between the principal plane of the objective lens and the plane containing the specimen surface.

4.5.3
contamination
extraneous surface layer on the specimen surface and/or localized build-up of foreign material on the surface arising from electron beam bombardment

4.5.4
coating
procedure of covering the specimen surface with a thin layer of material (usually conductive) which is generally created by vacuum evaporation or sputtering

4.5.5
edge effect
signal enhancement at edge features of the specimen surface in SEM images

4.6
signal detection
collection of the physical signals generated by the electron-specimen interaction and their conversion into electronic signals for further processing

4.6.1
detector
device employed to achieve signal collection and conversion into an electronic signal

4.6.2
electron detector
detector specifically designed for collection of electrons and their conversion into an electronic signal

4.6.2.1
BSE to SE conversion detector
version of the Everhart-Thornley detector for the collection of BSE signals through collection of remotely generated SEs by the use of a specific electrode having a high BSE to SE conversion efficiency

4.6.2.2
EBSD CCD-based camera
detector system, used for imaging of EBSD patterns, which involves a fluorescent screen, an optical camera lens system, a charge-coupled device and a computer to collect the data

4.6.2.3
IR camera
detector system used to observe the contents of the specimen chamber with infra-red light

4.6.2.4
channel plate detector
SE and BSE detector for all energy range operation and multiplication occurring within the capillaries through the detector plate with an accelerating potential applied between the exit and the entrance faces

4.6.2.5
combined scintillator/light guide BSE detector
dedicated BSE detector in which a large-area scintillator (made of the same material as the light guide) is placed above the specimen surface, close to and symmetrical with the surface, to achieve BSE collection over a solid angle of nearly 2π

4.6.2.6
environmental SE detector
gas (or gaseous) SE detector
special type of SE detector, dedicated to VPSEM or CPSEM, which operates on the principle of amplified ion signal current generated in the SE-gas ionization process by the accelerated SEs in the presence of an electric field produced by positively biasing an electrode near the specimen placed in a gaseous environment

4.6.2.7
Everhart-Thornley detector
type of SE detector named after its designers T. Everhart and R.F.M. Thornley

Note 1 to entry: The basic component of the detector is a scintillator that emits photons when hit by high-energy electrons. The emitted photons are collected by a light guide and transported to a photomultiplier for detection.

4.6.2.8
solid-state diode detector
dedicated BSE detector which operates on the principle of electron-hole production induced in a semiconductor by energetic electrons, with the features of flexible configuration, large solid angle, multiple arrays, energy selectivity and self-amplification

4.6.2.9
through-the-lens (TTL) detector
special kind of SE/BSE detector, adapted to the objective lens, in which the SEs/BSEs emitted from the specimen spiral up along the lens magnetic field, pass up through the lens bore and are collected by electron detector(s) placed on one side of the column

4.6.2.10
in-lens detector
special kind of SE/BSE detector, placed between the pole pieces of the objective lens, in which the SEs/BSEs emitted from the specimen spiral up along the lens magnetic field, pass up through the lens bore and are collected by electron detector(s) coaxial with the beam

4.6.3
take-off angle
angle between the surface of the specimen and the line connecting the beam impact point on the specimen surface to the centre of the detector face

Note 1 to entry: In this instance, the term does not apply to X-ray detector take-off angle. For X-ray detector take-off angle, see "X-ray take-off angle" in ISO 23833.

4.7
signal processing
subsequent treatment and modification of electrical signals leaving the detector by electronic means for further image processing and display

4.7.1
black level
dark level
minimum output signal from the amplifier that corresponds to the darkest possible level on the screen

4.7.2
dynamic range
difference between peak white and the black level

4.7.3
derivative processing
method of enhancing selected spatial frequencies in an image

5 Terms and definitions used in SEM image formation and processing

5.1
scanning
action of obtaining time-controlled movement of the electron probe on the specimen surface with the synchronized movement of the spot on the display screen

5.1.1
area scanning
scanning in an *x-y* pattern to obtain an SEM image display

5.1.2
line scanning
scanning in a single (*x* or *y*) direction to obtain the display of the signal modulation

5.1.2.1
***y* modulation**
operation of using the signal of intensity measured during the line scan to adjust the *y* deflection of the CRT to produce on the screen a curve displaying the distribution of intensity along the scan line

5.1.3
scanning distortion
loss of fidelity in a scanning image arising from defects in the scanning device or sometimes the scanning itself

5.1.3.1
Moiré effects
formation of Moiré fringes caused by the superposition of the periodicity of the specimen features and the grating of picture points forming the scanned image

5.2
SEM imaging
action of forming an image by a mapping operation that collects information from the specimen space and passes the information to the display space

5.2.1
analogue imaging
approach to SEM imaging in which the information collected from the specimen and the scanning control signal are treated and manipulated as continuous variables in the processing chain

5.2.2
digital imaging
approach to SEM imaging in which the information collected from the specimen and the scanning control signal are treated and manipulated as discrete variables, i.e. digitized in the processing chain, giving advantages over the analogue approach due to computer memory and data processing

5.2.2.1
digital resolution
number of discrete beam positions, i.e. the number of picture elements or "pixels"

EXAMPLE 512 × 512, 1 024 × 1 024.

5.2.2.2
intensity resolution
digital image depth
number of discrete levels in the digitized representation of the signal intensity, usually described as a power of 2

Note 1 to entry: 8 bits = 256 levels.

5.2.2.2.1

bit depth

colour depth

pixel depth

maximum number of discrete levels available for the digitized representation of the signal intensity, represented as a power of 2

Note 1 to entry: See 5.2.2.2.

Note 2 to entry: The most common bit depths for SEM are: 8 bits, 12 bits, 16 bits, 24 bits and 32 bits. Scientific grey-scale images are typically 8-bit, 12-bit or 16-bit, providing 256, 4 096 or 64 536 discrete grey levels.

5.2.3

depth of field

vertical distance required to bring the specimen from the optimum beam focus to a noticeably defocused position

5.2.4

picture element

pixel

smallest discrete image data element that constitutes an SEM image

5.2.5

pixel size

length of the pixel, measured at a specimen surface

Note 1 to entry: For a square or circular pixel, the horizontal and vertical pixel sizes should be the same.

5.3

contrast

C

difference in signal between two arbitrarily chosen points (P_1, P_2) of interest in the image field, normalized by the maximum possible signal available under the particular operating conditions

Note 1 to entry: Contrast is given by the equation

$$C = |S_2 - S_1|/S_{\max} \ (0 < C < 1)$$

where

S_2 and S_1 are the signals of two arbitrarily chosen points (P_1, P_2), respectively;

$S_{\max}$ is the maximum possible signal available under the particular operating conditions.

5.3.1

atomic number contrast

contrast that arises from a difference in the local chemical composition (atomic number or mass-fraction-averaged atomic number) within the specimen under study

5.3.2

channelling contrast

contrast that arises from the electron channelling effect through different Bragg diffraction conditions in a crystallographic specimen under study

5.3.3

contrast components

factors that influence the beam of electrons falling on the detector and thereby produce contrast in the specimen image

5.3.3.1

energy component

contrast component that arises when the contrast is carried by a certain portion of the electron energy distribution

5.3.3.2

number component

contrast component that arises as a result of different numbers of electrons leaving the specimen at different beam locations in response to changes in the specimen characteristics at those locations

5.3.3.3

trajectory component

contrast component that results from electrons leaving the specimen in different directions

5.3.4

crystallographic contrast

contrast that arises from electron channelling and diffraction as the result of interaction of beam electrons with the crystalline specimen

5.3.5

magnetic contrast

contrast that arises from interactions of the beam electrons with the magnetic field at the surface of or within the specimen

5.3.5.1

type 1 magnetic contrast

contrast that arises from interactions of the secondary electrons with the leakage magnetic field after they have exited the specimen surface

5.3.5.2

type 2 magnetic contrast

contrast that arises from the effect of the internal magnetic field upon the beam electrons as they initially scatter within the specimen

5.3.6

noise

time-varying disturbances superimposed on the analytical signal with fluctuations, leading to uncertainty in the signal intensity

Note 1 to entry: An accurate measure of noise can be determined from the standard deviation of the fluctuations. Visual or other estimates, such as peak-to-peak noise in a spectrum, may be useful as semiquantitative measures of noise.

Note 2 to entry: The fluctuations in the measured intensity can arise from a number of causes, such as statistical noise and electrical interference.

[SOURCE: ISO 18115-1:2013, definition 4.315]

5.3.7

Rose criterion

condition for an average observer to be able to distinguish small features in the presence of noise, which requires that the change in signal for the feature exceeds the noise by a factor of at least three

5.3.8

signal-to-noise ratio

ratio of signal to its noise

5.3.9

topographic contrast

contrast that arises from the difference in the local surface inclination of the specimen relative to the direction of the incident electron beam and to the position of the detector

5.3.9.1
surface tilt contrast
main topographic contrast mechanism that arises from the difference in the local surface inclination of the specimen relative to the direction of the incident electron beam and to the position of the detector

5.3.10
voltage contrast
contrast that arises from differences in surface potential from one location to another on the specimen

5.3.11
edge effect
enhanced or reduced emission of secondary electrons at high-aspect-ratio surface features

Note 1 to entry: The effect is dependent upon the interaction volume and the mean escape depth of secondary electrons from that volume as a function of beam position.

5.4
image distortion
loss of fidelity of dimensions in the SEM image

5.4.1
projection distortion
distortion that arises from the equivalent geometric projection effect on the SEM image when using a scan generated by rocking about a point on the central optic axis perpendicular to the specimen surface

5.4.1.1
gnomonic distortion
projection distortion that arises from the non-linear increment of the scan displacement with the scan angle from the central optic axis

5.4.1.2
foreshortening distortion
projection distortion that results from the tilt of a flat surface or randomly tilted facets of a specimen

5.5
analogue image processing
operation of treating and manipulating the image-information-carrying signals as continuously varying quantities

5.6
digital image processing
operation in which the image-information-carrying signals are treated and manipulated as discrete variables, i.e. digitized

5.6.1
digital image enhancement
category of digital image processing which seeks to render information in the image more readily visible to the operator

5.6.2
frame integration
mode of "real-time" image processing, using a *frame store* (5.6.3), which accumulates several incoming image frames, acquired at TV rates or at slower scan speeds, and integrates them to form a final mean image

5.6.3
buffer store
frame store
special dedicated computer memory board consisting of an array of memory registers adequate for temporarily storing the data of one or more images

5.6.4
graphics file format
image file format
archival digital format for storing the contents of the frame store

Note 1 to entry: The most popular image file formats are: bitmap (BMP), graphics interchange format (GIF), tagged image format (TIF) and joint photographic experts group (JPG). The TIF format is the scientific format that preserves all data and keeps the size of each pixel in its header. Consequently, this format is preferred to maintain the integrity of the images.

6 Terms and definitions used in SEM image interpretation and analysis

6.1
light-optical analogue
strong correspondence of the SEM imaging process using a positively biased E-T detector to the normal human vision process for scenes with illumination from above

6.2
electron beam induced current
EBIC
current that is induced in specimens of semiconductor material or semiconductor devices by electron beam bombardment

6.2.1
***β*-conductivity**
conductivity, such as the charge collection current, that exhibits variation in the absence of any electron voltaic effect

6.2.2
charge collection current
current that flows round a circuit connecting two contacts to the specimen in the EBIC condition

6.2.3
electron voltaic effect
generation of an electromotive force in the specimen, thus driving the charge collection current round an external circuit

6.2.4
specimen current
absorbed current
current flowing between the conducting specimen and ground

Note 1 to entry: It represents the difference between the beam current injected into the specimen and the current emitted as backscattered electrons and secondary electrons.

6.3
Bragg diffraction relation
mathematical expression which relates the wavelength of the incident radiation and the spacing of the atomic planes of a crystal to the angles, between the radiation beam and the atomic planes, at which diffraction takes place

Note 1 to entry: The mathematical expression is

$$n\lambda = 2d\sin\theta$$

where

d is the spacing of the atomic planes;

n is an integer;

λ is the wavelength of the radiation;

θ is the angle of diffraction.

6.4
electron channelling pattern
arrays of lines and bands observed in the SEM image of crystalline material, produced by the *channelling effect* (3.6)

6.5
electron backscattering diffraction pattern
EBSP
arrays of lines and bands observed in the SEM image of crystalline material, produced by *electron backscattering diffraction* (3.7.1)

6.5.1
Kikuchi lines
numerous systematic lines or bands observed in the EBSD pattern

6.6
cathodoluminescence
phenomenon of light emission from oxides or semiconductors bombarded by an electron beam

6.6.1
characteristic cathodoluminescence
cathodoluminescence that is dependent on the intrinsic properties of the specimen material

6.6.2
continuous excitation
operation of applying excitation in a continuous mode

6.6.3
decay time
length of time during which the intensity of luminescence fades to 1/e

6.6.4
donor-acceptor pair emission
luminescence emission caused by the radiative recombination of a donor-acceptor pair

6.6.5
electron-hole pair emission
luminescence emission caused by the radiative recombination of an electron-hole pair

6.6.6
extrinsic cathodoluminescence
cathodoluminescence that is dependent on the extrinsic impurities of the specimen material

6.6.7
luminescence centre
theoretically assumed locations representing impurity ions or defects in a crystal lattice where the process of luminescence can be produced by radiative electronic transition

6.6.8
pulse excitation
operation of applying excitation in a discrete mode

6.6.9
quantum yield
number of quanta emitted per quantum absorbed

6.6.10
quenching
physical process of radiationless deactivation of luminescence centres

7 Terms and definitions used in the measurement and calibration of SEM image magnification and resolution

7.1
electron probe
electron beam focused by the electron optical system onto the specimen

7.1.1
convergence angle
half-angle of the cone of the beam electrons converging onto the specimen

7.1.2
Gaussian probe diameter
full width at half maximum height (FWHM) of the intensity distribution of an aberration-free electron probe

7.1.3
maximum probe current
probe current calculated for a particular probe size at the optimum aperture angle and considering spherical aberration and diffraction effects, but neglecting chromatic effects

7.1.4
minimum probe size
probe size calculated for a particular probe current at the optimum aperture angle considering spherical aberration and diffraction effects, but neglecting chromatic aberration effects

7.2
image resolution
minimum spacing at which two features of the image can be recognized as distinct and separate

7.2.1
EBSD depth resolution
resolution, exclusively defined in the normal depth direction of the sample for EBSD, which is strongly dependent on the tilting of the specimen

7.2.2
EBSD lateral spatial resolution
resolution, exclusively defined in the lateral directions of the sample for EBSD, which is strongly dependent on the tilting of the specimen and is asymmetrical

7.2.3
threshold current
minimum beam current necessary to observe a certain level of contrast and to obtain a certain level of the signal-to-noise ratio under specified operating conditions

7.2.4
visibility limit
minimum level of contrast below which the features of the image are not visible

7.3
image magnification

M

ratio of the linear dimension L of the scan display (e.g. along an edge) to the corresponding length l of the scan field on the specimen $M = L/l$

Note 1 to entry: Historically, the magnification was related to the size of the film used to photograph the CRT image. For digital images displayable on screens of various sizes, it is more appropriate to specify the size of the scan field.

7.3.1
calibration grating

standard reference grating with a known pitch for calibration of the instrument with respect to the absolute value of magnification

Note 1 to entry: The value of the pitch of the grating can usually be traced to an authoritative standardization organization.

7.3.2
edge broadening

deterioration of the acutance of apparent edges of a structure in the image due to the finite beam diameter and the effect of electron diffusion in the solid state which degrades the imaging of edges or small surface details

7.4
binary SEM image

converted SEM image in which there are only two brightness levels

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