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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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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.

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ISO 22493 was prepared by Technical Committee ISO/TC 202, *Microbeam analysis*, Subcommittee SC 1, *Terminology*.

Introduction

The scanning electron microscopy (SEM) technique is used to observe and characterize the surface morphology and structure of solid materials, including 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 Abbreviations

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 X-ray spectrometer/spectrometry
EDX	energy dispersive X-ray 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 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 certain excitation conditions

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

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 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 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 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 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 the surface of a specimen as a result of bombardment by the primary electrons

NOTE 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 approximates measurement results by the use of random sampling techniques, usually using computer-generated random numbers in a way that adheres to the physical processes governing electron interaction

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 highly tilted specimen illuminated by the incident electron beam

4 Terms 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 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.