INTERNATIONAL STANDARD

ISO 18115-2

Second edition
2013-11-15

Surface chemical analysis — Vocabulary —

Part 2: Terms used in scanning-probe microscopy

Analyse chimique des surfaces — Vocabulaire —

Partie 2: Termes utilisés en microscopie à sonde à balayage

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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.

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

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The committee responsible for this document is ISO/TC 201, *Surface chemical analysis*, Subcommittee SC 1, *Terminology*.

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This second edition cancels and replaces the first edition (ISO 18115-2:2010), which has been technically revised.

ISO 18115 consists of the following parts, under the general title *Surface chemical analysis — Vocabulary*:

— *Part 1: General terms and terms used in spectroscopy*

— *Part 2: Terms used in scanning-probe microscopy*

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Introduction

Surface chemical analysis is an important area which involves interactions between people with different backgrounds and from different fields. Those conducting surface chemical analysis might be materials scientists, chemists, or physicists and might have a background that is primarily experimental or primarily theoretical. Those making use of the surface chemical data extend beyond this group into other disciplines.

With the present techniques of surface chemical analysis, compositional information is obtained for regions close to a surface (generally within 20 nm) and composition-versus-depth information is obtained with surface analytical techniques as surface layers are removed. The terms covered in this part of ISO 18115 relate to scanning-probe microscopy. The surface analytical terms covered in ISO 18115-1 extend from the techniques of electron spectroscopy and mass spectrometry to optical spectrometry and X-ray analysis. Concepts for these techniques derive from disciplines as widely ranging as nuclear physics and radiation science to physical chemistry and optics.

The wide range of disciplines and the individualities of national usages have led to different meanings being attributed to particular terms and, again, different terms being used to describe the same concept. To avoid the consequent misunderstandings and to facilitate the exchange of information, it is essential to clarify the concepts, to establish the correct terms for use, and to establish their definitions.

The terms and definitions in this International Standard have been prepared in conformance with the principles and style defined in ISO 1087-1:2000 and ISO 10241:1992. Essential aspects of these standards appear in 2.1 to 2.3. This part of ISO 18115 comprises the 98 abbreviations and 277 definitions of the combined ISO 18115-2:2010 and Amendment 1 to ISO 18115-2:2010. Corrections have been made to terms 3.23, 3.25, 3.36, 5.52, 5.53, 5.54, 5.55, 5.73, 5.83, and 5.151 that appeared in ISO 18115-2:2010. The terms are given in alphabetical order, classified under Clauses 3, 4, and 5 from the former International Standard with corrections and Clauses 6 and 7 from Amendment 1:

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Clause 3: Definitions of the scanning-probe microscopy methods;

Clause 4: Acronyms and terms for contact mechanics models;

Clause 5: Definitions of terms for scanning-probe methods;

Clause 6: Definitions of supplementary scanning-probe microscopy methods;

Clause 7: Definitions of supplementary terms for scanning-probe methods.

Many terms concerned with profilometry, or more correctly, surface texture measuring instruments, may be found in ISO 3274 and ISO 4287. ISO 3274 specifies the properties of the instrument that influence profile evaluation and provides basic considerations of the specification of contact (stylus) instruments (profile meter and profile recorder) whereas ISO 4287 concerns some issues involving surface texture.

Those interested in a more detailed understanding of profilometry or surface texture measuring instruments should consult ISO 3274, ISO 4287, ISO 25178, and other referenced documents.

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Surface chemical analysis — Vocabulary —

Part 2:
Terms used in scanning-probe microscopy

0 Scope

This International Standard defines terms for surface chemical analysis. ISO 18115-1 covers general terms and those used in spectroscopy while this part of ISO 18115 covers terms used in scanning-probe microscopy.

1 Abbreviated terms

In the list below, note that the final “M”, given as “microscopy”, may be taken equally as “microscope”, depending on the context. References to the entries where the abbreviations, or keywords in the abbreviations, are defined are given in brackets.

3D-PFM vector PFM (see 6.21)

AFM atomic-force microscopy (see 3.2)

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AM-AFM amplitude modulation atomic-force microscopy (see 6.1)

AM-KPFM amplitude modulation Kelvin-force microscopy (see 6.2)

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ANSOM apertureless near-field scanning optical microscopy (deprecated) (see 3.36)

ASNOM apertureless scanning near-field optical microscopy (deprecated) (see 3.36)

BEEM ballistic-electron emission microscopy (see. 5.8)

BEES ballistic-electron emission spectroscopy (see 5.8)

CFM chemical-force microscopy (see 3.3)

CITS current-imaging tunnelling spectroscopy (see 3.5)

CPAFM conductive-probe atomic-force microscopy (see 3.4)

CRAFM contact resonance atomic-force microscopy (see 6.4)

CRFM contact resonance force microscopy (see 6.4)

DFM dynamic-force microscopy (see 3.6)

DMM displacement modulation microscopy

DTM differential-tunnelling microscopy

EC-AFM electrochemical atomic-force microscopy (see 3.8)

ECFM electrochemical-force microscopy

EC-SPM electrochemical scanning-probe microscopy

EC-STM electrochemical scanning tunnelling microscopy (see 3.9)

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EFM	electrostatic-force microscopy (see 3.7)
FFM	frictional-force microscopy (see 3.11)
FM-AFM	frequency modulation atomic-force microscopy (see 3.10)
FM-KPFM	frequency modulation Kelvin-force microscopy (see 6.6)
FMM	force modulation microscopy (see 5.60)
FRET	fluorescent resonance energy transfer (see 5.54)
FS	force spectroscopy (see 5.58)
HFM	heterodyne force microscopy
HPICM	hopping probe ion conductance microscopy (see 6.7)
IC	intermittent contact (see 5.73)
IETS	inelastic electron tunnelling spectroscopy
IFM	interfacial-force microscopy
KFM	Kelvin-force microscopy (deprecated) (see 3.12)
KPM	Kelvin-probe microscopy (see 5.76)
KPFM	Kelvin-probe force microscopy (see 3.12)
LFM	lateral-force microscopy (see 3.13)
LFMM	lateral-force modulation microscopy (see 5.77)
MDFM	magnetic dynamic-force microscopy (see 3.14)
MDM	microwave dielectric microscopy
MFM	magnetic-force microscopy (see 3.15)
MOKE	magneto-optic Kerr effect
MRFM	magnetic-resonance force microscopy (see 3.16)
MTA	microthermal analysis
NC-AFM	non-contact atomic-force microscopy (see 3.18)
NIS	nanoimpedance spectroscopy
NSOM	near-field scanning optical microscopy (see 3.17)
PF-AFM	pulsed-force atomic-force microscopy (see 5.125)
PFM	piezoresponse force microscopy (see 5.100)
PSTM	photon scanning tunnelling microscopy
PTMS	photothermal micro-spectroscopy (see 3.19)
RNSOM	reflection near-field scanning optical microscopy (see 5.133)
RSNOM	reflection scanning near-field optical microscopy (see 5.133)

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SCFM scanning capacitance force microscopy (see 6.13)

SCM scanning capacitance microscopy (see 3.20)

SCPM scanning chemical-potential microscopy (see 3.21)

SECM scanning electrochemical microscopy (see 3.22)

SECM-SICM scanning electrochemical microscopy - scanning ion conductance microscopy (see 6.14)

SERRS surface-enhanced resonant Raman spectroscopy (see 5.154)

SERS surface-enhanced Raman scattering (see 5.151)

SFM scanning force microscopy (deprecated) (see 3.2)

SGM scanning gate microscopy

ShFM shear-force microscopy (see 3.37)

SHG second harmonic generation

SHPFM second harmonic piezo force microscopy

SHPM scanning Hall probe microscopy (see 3.23)

SICM scanning ion conductance microscopy (see 3.24)

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SIM scanning impedance microscopy

SKPM scanning Kelvin-probe microscopy (see 5.76)

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SMCM scanning micropipette contact method (see 6.17)

SMRM scanning magneto-resistance microscopy (see 3.25)

SMSM scanning Maxwell stress microscopy (see 3.26)

SMSM is sometimes given as SMM, but the latter acronym is also used for scanning microwave microscopy and scanning magnetic microscopy and so should not be used for scanning Maxwell stress microscopy.

SNDM scanning non-linear dielectric microscopy (see 3.29)

SNFUH scanning near-field ultrasound holography (see 3.28)

SNOM scanning near-field optical microscopy (see 3.17)

s-NSOM scattering near-field scanning optical microscopy (see 3.36)

SNTM scanning near-field thermal microscopy (see 3.27)

SPM scanning-probe microscopy (see 3.30)

SP-STM spin-polarized scanning tunnelling microscopy (see 3.38)

SP-STS spin-polarized scanning tunnelling spectroscopy (see 3.39)

SRTM spin-resolved tunnelling microscopy (deprecated) (see 3.38)

SSCM scanning surface confocal microscopy (see 6.18)

SSM scanning superconducting interference device (SQUID) microscopy

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s-SNOM	scattering scanning near-field optical microscopy (see 3.36)
SS-PFM	switching spectroscopy piezoresponse force microscopy (see 6.20)
SSPM	scanning surface potential microscopy (see 3.32)
SSRM	scanning spreading-resistance microscopy (see 3.31)
STM	scanning tunnelling microscopy (see 3.34)
SThM	scanning thermal microscopy (see 3.33)
STHM	scanning tunnelling hydrogen microscopy (see 6.19)
STS	scanning tunnelling spectroscopy (see 3.35)
SVM	scanning voltage microscopy
TECARS	tip-enhanced coherent anti-Stokes Raman scattering
TEFS	tip-enhanced fluorescence spectroscopy (see 3.41)
TERS	tip-enhanced Raman spectroscopy (see 3.42)
TNSOM	transmission near-field scanning optical microscopy
TSM	thermal-scanning microscopy (deprecated, see 3.33, Note 2)
TSNOM	transmission scanning near-field optical microscopy
UFM	ultrasonic force microscopy (see 3.43)

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2 Format

2.1 Use of terms printed boldface in definitions

A term printed in italics in a definition or a note is defined in another entry in either part of this International Standard. However, the term is printed in italics only the first time it occurs in each entry.

2.2 Non-preferred and deprecated terms

A term listed lightface is non-preferred or deprecated. The preferred term is listed boldface.

2.3 Subject fields

Where a term designates several concepts, it is necessary to indicate the subject field to which each concept belongs. The field is shown lightface, between angle brackets, preceding the definition, and on the same line.

3 Definitions of the scanning-probe microscopy methods

NOTE The following are the definitions of scanned probe microscopy methods. In the list below, note that the final “M” or final “S” in the acronyms, given as “microscopy” or “spectroscopy”, may also mean “microscope” or “spectrometer”, respectively, depending on the context. For the definition relating to the microscope or spectrometer, replace the words “a method” by the words “an instrument” where that appears.

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3.1
apertureless Raman microscopy
<NSOM, SNOM> method of microscopy involving the acquisition of Raman spectroscopic data utilizing a *near-field* (5.88) optical source and based upon a metal *tip* (5.120) in close proximity to the sample surface illuminated with suitably polarized light

3.2
atomic-force microscopy
AFM
DEPRECATED: scanning force microscopy
DEPRECATED: SFM
method for imaging surfaces by mechanically scanning their surface contours, in which the deflection of a sharp *tip* (5.120) sensing the surface forces, mounted on a compliant *cantilever* (5.18), is monitored

Note 1 to entry: AFM can provide a quantitative height *image* (5.69) of both insulating and conducting surfaces.

Note 2 to entry: Some AFM instruments move the sample in the *x*-, *y*- and *z*-directions while keeping the tip position constant and others move the tip while keeping the sample position constant.

Note 3 to entry: AFM can be conducted in vacuum, a liquid, a controlled atmosphere, or air. Atomic resolution may be attainable with suitable samples, with sharp tips, and by using an appropriate imaging mode.

Note 4 to entry: Many types of force can be measured, such as the *normal forces* (5.91) or the *lateral* (5.77), *friction* (5.62), or shear force. When the latter is measured, the technique is referred to as *lateral* (3.13), *frictional* (3.11), or *shear force microscopy* (3.37). This generic term encompasses all of the types of force microscopy listed in Clause 1.

Note 5 to entry: AFMs can be used to measure surface normal forces at individual points in the pixel array used for imaging.

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Note 6 to entry: For typical AFM tips with radii < 100 nm, the normal force should be less than about 0,1 µN, depending on the sample material, or irreversible surface deformation and excessive tip wear occur.

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3.3
chemical-force microscopy
CFM
LFM (3.13) or *AFM* (3.2) mode in which the deflection of a sharp *probe tip* (5.120), functionalized to provide interaction forces with specific molecules, is monitored

Note 1 to entry: LFM is the most popularly used mode.

3.4
conductive-probe atomic-force microscopy
CPAFM
DEPRECATED: CAFM
DEPRECATED: C-AFM
<AFM> *AFM* (3.2) mode in which a conductive *probe* (5.109) is used to measure both topography and electric current between the *tip* (5.120) and the sample

Note 1 to entry: CPAFM is a secondary imaging mode derived from contact AFM that characterizes conductivity variations across medium- to low-conducting and semiconducting materials. Typically, a DC bias is applied to the tip, and the sample is held at ground potential. While the *z* feedback signal is used to generate a normal-contact AFM topography *image* (5.69), the current passing between the tip and the sample is measured to generate the conductive AFM image.

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3.5
current-imaging tunnelling spectroscopy
CITS
<STM> method in which the STM tip is held at a constant height above the surface, while the bias voltage, V, is scanned and the tunnelling current, I, is measured and mapped

Note 1 to entry: The constant height is usually maintained by gating the feedback loop so that it is only active for some proportion of the time; during the remaining time, the feedback loop is switched off and the applied tip bias is ramped and the current is measured.

Note 2 to entry: See *I-V spectroscopy* (5.74).

3.6
dynamic-mode AFM
dynamic-force microscopy
DFM
<AFM> *AFM* (3.2) mode in which the relative positions of the *probe tip* (5.120) and sample vary in a sinusoidal manner at each point in the *image* (5.69)

Note 1 to entry: The sinusoidal oscillation is usually in the form of a vibration in the z-direction and is often driven at a frequency close to, and sometimes equal to, the cantilever resonance frequency.

Note 2 to entry: The signal measured can be the amplitude, the phase shift, or the resonance frequency shift of the cantilever.

3.7
electrostatic-force microscopy
DEPRECATED: electric-force microscopy
<AFM> *AFM* (3.2) mode in which a conductive *probe* (5.109) is used to map both topography and electrostatic force between the *tip* (5.120) and the sample surface

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3.8
electrochemical atomic-force microscopy
EC-AFM
<AFM> *AFM* (3.2) mode in which a conductive *probe* (5.109) is used in an electrolyte solution to measure both topography and electrochemical current

3.9
electrochemical scanning tunnelling microscopy
EC-STM
<STM> *STM* (3.34) mode in which a coated *tip* (5.120) is used in an electrolyte solution to measure both topography and electrochemical current

3.10
frequency modulation atomic-force microscopy
FM-AFM
dynamic-mode AFM (3.6) in which the shift in *resonance frequency* (5.134) of the *probe assembly* (5.20) is monitored and is adjusted to a set point using a feedback circuit

3.11
frictional-force microscopy
FFM
SPM (3.30) mode in which the *friction force* (5.62) is monitored

Note 1 to entry: The friction force can be detected in a static or frequency-modulated mode. Information on the tilt azimuthal variation of the frictional force needs the static mode.

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3.12
Kelvin-probe force microscopy
KPFM
DEPRECATED: KFM
dynamic-mode AFM (3.6) using a conducting probe tip to measure spatial or temporal changes in the relative electric potentials of the tip and the surface

Note 1 to entry: Changes in the relative potentials reflect changes in the surface *work function* (4.487).

3.13
lateral-force microscopy
LFM
SPM (3.30) mode in which surface contours are scanned with a *probe assembly* (5.20) while monitoring the lateral forces exerted on the *probe tip* (5.120) by observation of the torsion of the *cantilever* (5.18) arising as a result of those forces

Note 1 to entry: The lateral forces can be detected in a static or frequency-modulated mode. Information on the tilt azimuth of surface molecules needs the static mode.

3.14
magnetic dynamic-force microscopy
MDFM
DEPRECATED: magnetic AC mode
DEPRECATED: MAC mode
<AFM> *AFM* (3.2) mode in which the *probe* (5.109) is oscillated by using a *magnetic force* (5.80)

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3.15
magnetic-force microscopy
MFM
AFM (3.2) mode employing a *probe assembly* (5.20) that monitors both atomic forces and magnetic interactions between the *probe tip* (5.120) and a surface

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3.16
magnetic-resonance force microscopy
MRFM
<AFM> *AFM* (3.2) imaging mode in which magnetic signals are mechanically detected by using a *cantilever* (5.18) at resonance and the force arising from nuclear or electronic spin in the sample is sensitively measured

3.17
near-field scanning optical microscopy
NSOM
scanning near-field optical microscopy
SNOM
method of imaging surfaces optically in transmission or reflection by mechanically scanning an optically active *probe* (5.109) much smaller than the wavelength of light over the surface while monitoring the transmitted or reflected light or an associated signal in the *near-field* (5.88) regime

Note 1 to entry: See *scattering NSOM* (3.36), *scattering SNOM* (3.36).

Note 2 to entry: Topography is important and the probe is scanned at constant height. Usually, the probe is oscillated in the shear mode to detect and set the height.

Note 3 to entry: Where the extent of the optical probe is defined by an *aperture* (5.5), the aperture size is typically in the range of 10 nm to 100 nm, and this largely defines the resolution. This form of instrument is often called an aperture NSOM or aperture SNOM to distinguish it from a *scattering NSOM* (3.36) or *scattering SNOM* (3.36) [previously called *apertureless NSOM* (3.36) or *apertureless SNOM* (3.36)], although, generally, the adjective “aperture” is omitted. In the apertureless form, the extent of the optically active probe is defined by an illuminated sharp metal or metal-coated *tip* (5.120) with a radius typically in the range of 10 nm to 100 nm, and this largely defines the resolution.

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Note 4 to entry: In addition to the optical *image* (5.69), NSOM can provide a quantitative image of the surface contours similar to that available in *AFM* (3.2) and allied scanning-probe techniques.

Note 5 to entry: This generic term encompasses all of the types of near-field microscopy listed in Clause 2.

3.18
non-contact atomic-force microscopy
NC-AFM
dynamic-mode AFM (3.6) in which the *probe tip* (5.120) is operated at such a distance from the surface that it samples the weak, attractive van der Waals or other forces

Note 1 to entry: Forces in this mode are very low and are best for studying soft materials or avoiding cross-contamination of the tip and the surface.

3.19
photothermal micro-spectroscopy
PTMS
SThM mode in which the *probe* (5.109) detects the photothermal response of a sample exposed to infrared light to obtain an absorption spectrum

Note 1 to entry: The infrared light can be either from a tuneable monochromatic source or from a broadband source set up as part of a Fourier transform infrared spectrometer. In the latter case, the photothermal temperature fluctuations can be measured as a function of time to provide an interferogram which is Fourier-transformed to give the spectrum of sub-micron-sized regions of the sample.

3.20
scanning capacitance microscopy
SCM
SPM (3.30) mode in which a conductive *probe* (5.109) is used to measure both topography and capacitance between the *tip* (5.120) and sample

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3.21
scanning chemical-potential microscopy
SCPM
SPM (3.30) mode in which spatial variations in the thermoelectric voltage signal, created by a constant temperature gradient normal to the sample surface, are measured and related to spatial variations in the chemical-potential gradient

3.22
scanning electrochemical microscopy
SECM
SPM (3.30) mode in which imaging occurs in an electrolyte solution with an electrochemically active *tip* (5.120)

Note 1 to entry: See *electrochemical atomic-force microscopy* (3.8), *EC-AFM* (3.8), *electrochemical scanning-probe microscopy* (6.5), *EC-SPM* (6.5), *electrochemical scanning tunnelling microscopy* (3.9), *EC-STM* (3.9).

Note 2 to entry: In most cases, the SECM tip is an ultramicroelectrode and the tip signal is a Faradaic current from electrolysis of solution species.

Note 3 to entry: The potential difference between the tip and either the sample or a reference electrode is usually monitored.

Note 4 to entry: The liquid is usually an ionic or polar liquid in which an electric double layer exists at the sample surface.

Note 5 to entry: The surface may be scanned with the tip at a constant height in the instrument frame to measure the convolution of topography and electrochemical activity, or if the sample is electrochemically homogeneous, in a feedback mode so that the tip is at a constant distance from the sample surface and the topography of the surface is recorded.

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3.23
scanning Hall probe microscopy
SHPM
SPM (3.30) mode in which a Hall probe is used as the scanning sensor to measure and map the magnetic field from a sample surface

3.24
scanning ion conductance microscopy
SICM
SPM (3.30) mode in which an electrolyte-filled micropipette or nanopipette is used as a local *probe* (5.109) for insulating samples immersed in an electrolytic solution

Note 1 to entry: The distance dependence of the ion conductance provides the key to performing non-contact surface profiling.

3.25
scanning magneto-resistance microscopy
SMRM
SPM (3.30) mode in which a magneto-resistive sensor *probe* (5.109) on a *cantilever* (5.18) is scanned in the *contact mode* (5.35) over a magnetic sample surface to measure two-dimensional magnetic *images* (5.69) by acquiring magneto-resistive voltage

3.26
scanning Maxwell stress microscopy
SMSM
SPM (3.30) mode in which a conductive *probe* (5.109) is used to measure both topography and surface potential by utilizing the Maxwell stress

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3.27
scanning near-field thermal microscopy
SNTM
SNOM method in which an infrared-sensing thermometer is used to detect the local emission collected by an optical *probe* (5.109) to measure both the topography and thermal properties

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3.28
scanning near-field ultrasound holography
SNFUH
method for imaging surfaces and the subsurface regimes by mechanically scanning their surface contours and detecting the results of the interference of a high-frequency acoustic wave [of the order of MHz or higher and substantially greater than the *resonance frequency* (5.134) of the *cantilever* (5.18)] applied to the bottom of the sample while another wave is applied to the cantilever at a slightly different frequency

3.29
scanning non-linear dielectric microscopy
SNDM
SPM (3.30) mode in which a conductive *probe* (5.109) is used to measure both topography and dielectric constant (capacitance)

3.30
scanning-probe microscopy
SPM
method of imaging surfaces by mechanically scanning a *probe* (5.109) over the surface under study, in which the concomitant response of a detector is measured

Note 1 to entry: This generic term encompasses *AFM* (3.2), *CFM* (3.3), *CITS* (3.5), *FFM* (3.11), *LFM* (3.13), SFM, *SNOM* (3.17), *STM* (3.34), TSM, etc. listed in Clause 1.

Note 2 to entry: The resolution varies from that of STM, where individual atoms can be resolved, to *SThM* (3.33), in which the resolution is generally limited to around 1 µm.

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