INTERNATIONAL STANDARD

ISO 18115-2

First edition
2010-07-15

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

Reference number
ISO 18115-2:2010(E)

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Published in Switzerland

Contents

Page

Foreword iv
Introduction v
1 Scope 1
2 Abbreviations 1
3 Format 4
3.1 Use of terms printed boldface in definitions 4
3.2 Non-preferred and deprecated terms 4
3.3 Subject fields 4
4 Definitions of the scanning-probe microscopy methods 4
5 Acronyms and terms for contact mechanics models 11
6 Terms for scanning-probe methods 13
Bibliography 37
Alphabetical index of terms in this part of ISO 18115 38
Alphabetical index of terms in ISO 18115-1 42

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.

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.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 18115-2 was prepared by Technical Committee ISO/TC 201, *Surface chemical analysis*, Subcommittee SC 1, *Terminology*.

Together with Part 1 (see below), it cancels and replaces ISO 18115:2001, which has been split into two parts and at the same time technically revised. The two parts also incorporate the Amendments ISO 18115:2001/Amd.1:2006 and ISO 18115:2001/Amd.2:2007.

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*

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 Part 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 the two parts of ISO 18115 have been prepared in conformance with the principles and style defined in ISO 1087-1:2000, *Terminology work — Vocabulary — Part 1: Theory and application*, and ISO 10241:1992, *International terminology standards — Preparation and layout*. Essential aspects of these standards appear in Subclauses 3.1 to 3.3. The terms are given in alphabetical order, classified under three headings:

Clause 4: Definitions of the scanning-probe microscopy methods.

Clause 5: Acronyms and terms for contact mechanics models.

Clause 6: Definitions of terms for scanning-probe methods.

A single alphabetical index to this part of ISO 18115 is given after the Bibliography. To help users, a second index is provided for the terms in Part 1 covering the general terms and terms used in spectroscopy. To assist retrieval, compound terms can be found in the indexes in both natural and reverse word order.

This part of ISO 18115 contains new terms in addition to those terms, previously published in ISO 18115:2001/Amd.2, that involve scanning-probe microscopy. All other terms now appear in ISO 18115-1.

Surface chemical analysis — Vocabulary —

Part 1:
Terms used in scanning-probe microscopy

1 Scope

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

2 Abbreviations

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 key words in the abbreviations, are defined are given in brackets.

AFM atomic-force microscopy (see 4.3)

ANSOM apertureless near-field scanning optical microscopy (deprecated) (see 4.37)

ASNOM apertureless scanning near-field optical microscopy (deprecated) (see 4.37)

BEEM ballistic-electron emission microscopy (cf. 6.8)

BEES ballistic-electron emission spectroscopy (cf. 6.8)

CPAFM conductive-probe atomic-force microscopy (see 4.5)

CFM chemical-force microscopy (see 4.4)

CITS current-imaging tunnelling spectroscopy (see 4.6)

DFM dynamic-force microscopy (see 4.7)

DMM displacement modulation microscopy

DTM differential-tunnelling microscopy

EC-AFM electrochemical atomic-force microscopy (see 4.9)

ECFM electrochemical-force microscopy

EC-SPM electrochemical scanning-probe microscopy

EC-STM electrochemical scanning tunnelling microscopy (see 4.10)

EFM electrostatic-force microscopy (see 4.8)

FFM	frictional-force microscopy (see 4.12)
FM-AFM	frequency modulation atomic-force microscopy (see 4.11)
FMM	force modulation microscopy (cf. 6.60)
FRET	fluorescent resonance energy transfer (see 6.54)
FS	force spectroscopy (see 6.58)
HFM	heterodyne force microscopy
IC	intermittent contact (see 6.73)
IETS	inelastic electron tunnelling spectroscopy
IFM	interfacial-force microscopy
KFM	Kelvin force microscopy (deprecated) (see 4.13)
KPM	Kelvin probe microscopy (cf. 6.76)
KPFM	Kelvin-probe force microscopy (see 4.13)
LFM	lateral-force microscopy (see 4.14)
LFMM	lateral-force modulation microscopy (cf. 6.77)
MDFM	magnetic dynamic-force microscopy (see 4.15)
MDM	microwave dielectric microscopy
MFM	magnetic-force microscopy (see 4.16)
MOKE	magneto-optic Kerr effect
MRFM	magnetic-resonance force microscopy (see 4.17)
MTA	micro-thermal analysis
NC-AFM	non-contact atomic-force microscopy (see 4.19)
NIS	nano-impedance spectroscopy
NSOM	near-field scanning optical microscopy (see 4.18)
PF-AFM	pulsed-force atomic-force microscopy (cf. 6.125)
PFM	piezoresponse force microscopy (cf. 6.100)
PSTM	photon scanning tunnelling microscopy
PTMS	photothermal micro-spectroscopy (see 4.20)
RNSOM	reflection near-field scanning optical microscopy (see 6.133)
RSNOM	reflection scanning near-field optical microscopy (cf. 6.133)
SCM	scanning capacitance microscopy (see 4.21)

SCPM	scanning chemical-potential microscopy (see 4.22)
SECM	scanning electrochemical microscopy (see 4.23)
SERRS	surface-enhanced resonant Raman spectroscopy (see 6.154)
SERS	surface-enhanced Raman scattering (see 6.151)
SFM	scanning force microscopy (deprecated) (see 4.3)
SGM	scanning gate microscopy
ShFM	shear-force microscopy (see 4.38)
SHG	second harmonic generation
SHPFM	second harmonic piezo force microscopy
SHPM	scanning Hall probe microscopy (see 4.24)
SICM	scanning ion conductance microscopy (see 4.25)
SIM	scanning impedance microscopy
SKPM	scanning Kelvin probe microscopy (cf. 6.76)
SMRM	scanning magneto-resistance microscopy (see 4.26)
SMSM	scanning Maxwell stress microscopy (see 4.27)

NOTE 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 4.30)
SNFUH	scanning near-field ultrasound holography (see 4.29)
SNOM	scanning near-field optical microscopy (see 4.18)
SNTM	scanning near-field thermal microscopy (see 4.28)
SPM	scanning-probe microscopy (see 4.31)
SP-STM	spin-polarized scanning tunnelling microscopy (see 4.39)
SP-STS	spin-polarized scanning tunnelling spectroscopy (see 4.40)
SRTM	spin-resolved tunnelling microscopy (deprecated) (see 4.39)
SSM	scanning superconducting interference device (SQUID) microscopy
s-NSOM	scattering near-field scanning optical microscopy (see 4.37)
s-SNOM	scattering scanning near-field optical microscopy (see 4.37)
SSPM	scanning surface potential microscopy (see 4.33)
SSRM	scanning spreading-resistance microscopy (see 4.32)

STM	scanning tunnelling microscopy (see 4.35)
SThM	scanning thermal microscopy (see 4.34)
STS	scanning tunnelling spectroscopy (see 4.36)
SVM	scanning voltage microscopy
TECARS	tip-enhanced coherent anti-Stokes Raman scattering
TEFS	tip-enhanced fluorescence spectroscopy (see 4.42)
TEOS	tip-enhanced optical spectroscopy
TERS	tip-enhanced Raman scattering (see 4.43)
TNSOM	transmission near-field scanning optical microscopy
TSM	thermal-scanning microscopy (deprecated, see 4.34, Note 2)
TSNOM	transmission scanning near-field optical microscopy
UFM	ultrasonic force microscopy (see 4.44)

3 Format

3.1 Use of terms printed boldface in definitions

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

3.2 Non-preferred and deprecated terms

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

3.3 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, on the same line.

4 Definitions of the scanning-probe microscopy methods

4.1 The following are the definitions of scanned probe microscopy methods. In the list below, note that the final "M" and 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.

4.2
apertureless Raman microscopy
⟨NSOM, SNOM⟩ a method of microscopy involving the acquisition of Raman spectroscopic data utilizing a **near-field** optical source and based upon a metal **tip** in close proximity to the sample surface illuminated with suitably polarized light

4.3
atomic-force microscopy
AFM
scanning force microscopy (deprecated)
SFM (deprecated)
a method for imaging surfaces by mechanically scanning their surface contours, in which the deflection of a sharp **tip** sensing the surface forces, mounted on a compliant **cantilever**, is monitored

NOTE 1 AFM can provide a quantitative height **image** of both insulating and conducting surfaces.

NOTE 2 Some AFM instruments move the sample in the x-, y- and z-directions whilst keeping the tip position constant and others move the tip whilst keeping the sample position constant.

NOTE 3 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 Many types of force can be measured, such as the **normal forces** or the **lateral, friction or shear force**. When the latter is measured, the technique is referred to as **lateral**, **frictional** or **shear force microscopy**. This generic term encompasses all of the types of force microscopy listed in Clause 2.

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

NOTE 6 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 occurs.

4.4
chemical-force microscopy
CFM
an **LFM** or **AFM** mode in which the deflection of a sharp **probe tip**, functionalized to provide interaction forces with specific molecules, is monitored

NOTE LFM is the most popularly used mode.

4.5
conductive-probe atomic-force microscopy
CPAFM
CAFM (deprecated)
C-AFM (deprecated)
⟨AFM⟩ an **AFM** mode in which a conductive **probe** is used to measure both topography and electric current between the **tip** and the sample

NOTE 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**, the current passing between the tip and sample is measured to generate the conductive AFM image.

4.6
current-imaging tunnelling spectroscopy
CITS
⟨STM⟩ a 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 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.

cf. **I-V spectroscopy**

4.7
dynamic-mode AFM
dynamic-force microscopy
DFM
⟨AFM⟩ an **AFM** mode in which the relative positions of the **probe tip** and sample vary in a sinusoidal manner at each point in the **image**

NOTE 1 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 The signal measured can be the amplitude, the phase shift or the resonance frequency shift of the cantilever.

4.8
electrostatic-force microscopy
electric-force microscopy (deprecated)
EFM
⟨AFM⟩ an **AFM** mode in which a conductive **probe** is used to map both topography and electrostatic force between the **tip** and the sample surface

4.9
electrochemical atomic-force microscopy
EC-AFM
⟨AFM⟩ an **AFM** mode in which a conductive **probe** is used in an electrolyte solution to measure both topography and electrochemical current

4.10
electrochemical scanning tunnelling microscopy
EC-STM
⟨STM⟩ an **STM** mode in which a coated **tip** is used in an electrolyte solution to measure both topography and electrochemical current

4.11
frequency modulation atomic-force microscopy
FM-AFM
dynamic-mode AFM in which the shift in **resonance frequency** of the **probe assembly** is monitored and is adjusted to a setpoint using a feedback circuit

4.12
frictional-force microscopy
FFM
an **SPM** mode in which the **friction force** is monitored

NOTE 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.

4.13
Kelvin-probe force microscopy
KPFM
KFM (deprecated)
dynamic-mode AFM using a conducting **probe tip** to measure spatial or temporal changes in the relative electric potentials of the tip and the surface

NOTE Changes in the relative potentials reflect changes in the surface **work function**.

4.14
lateral-force microscopy
LFM
an **SPM** mode in which surface contours are scanned with a **probe assembly** whilst monitoring the lateral forces exerted on the **probe tip** by observation of the torsion of the **cantilever** arising as a result of those forces

NOTE 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.

4.15
magnetic dynamic-force microscopy
MDFM
magnetic AC mode (deprecated)
MAC mode (deprecated)
⟨AFM⟩ an **AFM** mode in which the **probe** is oscillated by using a **magnetic force**

4.16
magnetic-force microscopy
MFM
an **AFM** mode employing a **probe assembly** that monitors both atomic forces and magnetic interactions between the **probe tip** and a surface

4.17
magnetic-resonance force microscopy
MRFM
⟨AFM⟩ an **AFM** imaging mode in which magnetic signals are mechanically detected by using a **cantilever** at resonance and the force arising from nuclear or electronic spin in the sample is sensitively measured

4.18
near-field scanning optical microscopy
NSOM
scanning near-field optical microscopy
SNOM
a method of imaging surfaces optically in transmission or reflection by mechanically scanning an optically active **probe** much smaller than the wavelength of light over the surface whilst monitoring the transmitted or reflected light or an associated signal in the **near-field** regime

cf. **scattering NSOM**, **scattering SNOM**

NOTE 1 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 2 Where the extent of the optical probe is defined by an **aperture**, the aperture size is typically in the range 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** or **scattering SNOM** (previously called **apertureless NSOM** or **apertureless SNOM**) 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** with a radius typically in the range 10 nm to 100 nm, and this largely defines the resolution.

NOTE 3 In addition to the optical **image**, NSOM can provide a quantitative image of the surface contours similar to that available in **AFM** and allied scanning-probe techniques.

NOTE 4 This generic term encompasses all of the types of near-field microscopy listed in Clause 2.

4.19
non-contact atomic-force microscopy
NC-AFM
dynamic-mode AFM in which the **probe tip** is operated at such a distance from the surface that it samples the weak, attractive, van der Waals or other forces

NOTE Forces in this mode are very low and are best for studying soft materials or avoiding cross-contamination of the tip and the surface.

4.20
photothermal micro-spectroscopy
PTMS
an **SThM** mode in which the **probe** detects the photothermal response of a sample exposed to infrared light to obtain an absorption spectrum

NOTE 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.

4.21
scanning capacitance microscopy
SCM
an **SPM** mode in which a conductive **probe** is used to measure both topography and capacitance between the **tip** and sample

4.22
scanning chemical-potential microscopy
SCPM
an **SPM** 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

4.23
scanning electrochemical microscopy
SECM
an **SPM** mode in which imaging occurs in an electrolyte solution with an electrochemically active **tip**

NOTE In most cases, the SECM tip is an ultra-microelectrode and the tip signal is a Faradaic current from electrolysis of solution species.

4.24
scanning Hall probe microscopy
SHPM
an **SPM** mode in which a Hall probe is used as the scanning sensor to measure and map the magnetic field from a sample surface

4.25
scanning ion conductance microscopy
SICM
an **SPM** mode in which an electrolyte-filled micropipette is used as a local **probe** for insulating samples immersed in an electrolytic solution

NOTE The distance dependence of the ion conductance provides the key to performing non-contact surface profiling.

4.26
scanning magneto-resistance microscopy
SMRM
an **SPM** mode in which a magneto-resistive sensor **probe** on a **cantilever** is scanned in the **contact mode** over a magnetic sample surface to measure two-dimensional magnetic **images** by acquiring magneto-resistive voltage

4.27
scanning Maxwell stress microscopy
SMSM
an **SPM** mode in which a conductive **probe** is used to measure both topography and surface potential by utilizing the Maxwell stress

4.28
scanning near-field thermal microscopy
SNTM
a SNOM method in which an infrared-sensing thermometer is used to detect the local emission collected by an optical **probe** to measure both the topography and thermal properties

4.29
scanning near-field ultrasound holography
SNFUH
a 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** of the **cantilever**) applied to the bottom of the sample while another wave is applied to the cantilever at a slightly different frequency

4.30
scanning non-linear dielectric microscopy
SNDM
an **SPM** mode in which a conductive **probe** is used to measure both topography and dielectric constant (capacitance)

4.31
scanning-probe microscopy
SPM
a method of imaging surfaces by mechanically scanning a **probe** over the surface under study, in which the concomitant response of a detector is measured

NOTE 1 This generic term encompasses **AFM**, **CFM**, **CITS**, **FFM**, **LFM**, SFM, **SNOM**, **STM**, TSM, etc., listed in Clause 2.

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

4.32
scanning spreading-resistance microscopy
SSRM
an **SPM** mode in which a conductive **tip** is used to measure both topography and spreading resistance

NOTE Whilst full-diamond or diamond-coated **probes** are almost always used for the SSRM of Si samples, it is possible to perform SSRM with other conductive tips when (in cases such as the imaging of InP, which is soft) the use of a diamond tip could damage the sample.

4.33
scanning surface potential microscopy
SSPM
an **SPM** mode in which a conductive **probe** is used to measure both topography and surface potential

NOTE **KPFM** is SSPM conducted using an **AFM** as defined in 4.13. Where this is appropriate, KPFM should be used to describe the method rather than the more generic term, SSPM.

4.34
scanning thermal microscopy
SThM
an **SPM** method in which a thermal sensor is integrated into the **probe** to measure both topography and thermal properties

NOTE 1 Examples of such thermal properties are temperature and thermal conductivity.

NOTE 2 This method is sometimes known as thermal-scanning microscopy or TSM. This expression and acronym are deprecated.

4.35
scanning tunnelling microscopy
STM
an **SPM** mode for imaging conductive surfaces by mechanically scanning a sharp, voltage-biased, conducting **probe tip** over their surface, in which the data of the **tunnelling** current and the tip-surface separation are used in generating the **image**

NOTE 1 STM can be conducted in vacuum, a liquid or air. Atomic resolution can be achieved with suitable samples and sharp probes and can, with ideal samples, provide localized bonding information around surface atoms.

NOTE 2 Images can be formed from the height data at a constant tunnelling current or the tunnelling current at a constant height or other modes at defined relative potentials of the tip and sample.

NOTE 3 STM can be used to map the densities of states at surfaces or, in ideal cases, around individual atoms. The surface images can differ significantly, depending on the **tip bias**, even for the same topography.

4.36
scanning tunnelling spectroscopy
STS
an **STM** mode in which the **tunnelling** current, I, between **tip** and sample is measured as the voltage, V, between the tip and sample as the sample is scanned

cf. **I-V spectroscopy**

NOTE The differential conductance, $\mathrm{d}I/\mathrm{d}V$, reflects the electronic local density of states (LDOS). If the sample is a superconductor, the energy gap around the Fermi level can be characterized.

4.37
scattering NSOM/SNOM
s-NSOM
s-SNOM
apertureless NSOM (deprecated)
ANSOM (deprecated)
apertureless SNOM (deprecated)
ASNOM (deprecated)
a method in which imaging at a resolution below the **Abbe diffraction limit** is achieved by detecting light scattered or emitted in the vicinity of a sharp scanning **tip**

NOTE 1 ASNOM and ANSOM are both commonly used, and sometimes also mean apertured NSOM/SNOM and apertureless NSOM/SNOM. To reduce the potential confusion, scattering NSOM/SNOM is recommended, which is more descriptive of the technique than the earlier terms which describe what is not used.

NOTE 2 No **aperture** defines the resolution of the instrument. Instead, the probed volume is defined by scattering within the near-field region around the tip or the localized optical field distribution around the tip.

NOTE 3 The sharp tip is usually metallic or metal-coated, permitting measurements of **surface-enhanced Raman** and **fluorescence** spectroscopy and **second harmonic generation**. Raman signals of molecules in close proximity to silver can be enhanced by a factor of 10^{14}.

NOTE 4 The tip can be a single fluorescent molecule or **nanoparticle**.

NOTE 5 In the literature, the acronym ANSOM or ASNOM is occasionally used erroneously for aperture NSOM or aperture SNOM.

4.38
shear force microscopy
ShFM
⟨AFM⟩ an **AFM** mode using signals arising from a **probe tip** oscillating laterally in proximity to the surface

NOTE The oscillation is usually sinusoidal and generated through a piezoelectric actuator.

4.39
spin-polarized scanning tunnelling microscopy
SP-STM
spin-resolved tunnelling microscopy (deprecated)
SRTM (deprecated)
⟨STM⟩ an **STM** mode in which a magnetically ordered (ferromagnetic or antiferromagnetic) STM **tip** is scanned over a sample surface to image two-dimensional magnetic structures on the nanometre scale by measuring the spin-dependent **tunnelling** current

4.40
spin-polarized scanning tunnelling spectroscopy
SP-STS
an **STS** mode in which a magnetically ordered (ferromagnetic or antiferromagnetic) **STM tip** is scanned over a sample surface to perform spin-polarized **tunnelling** spectroscopy to probe the magnetic and electronic structures of the sample surface on the nanometre scale

4.41
static-mode AFM
static AFM
⟨AFM⟩ an **AFM** mode of scanning the **probe** where a control parameter is maintained essentially constant or of scanning a control parameter at a fixed point in the raster array at the sample surface

NOTE The control parameter can be, for example, force or height.

4.42
tip-enhanced fluorescence spectroscopy
TEFS
⟨NSOM, SNOM⟩ enhanced fluorescence observed with a metal **tip** in close proximity to a sample surface illuminated with suitably polarized light

cf. **tip-enhanced Raman scattering**

4.43
tip-enhanced Raman spectroscopy
TERS
⟨NSOM, SNOM⟩ enhanced **Raman effect** observed with a metal **tip** in close proximity to a sample surface illuminated with suitably polarized light

cf. **tip-enhanced fluorescence spectroscopy**, **surface-enhanced Raman scattering**

4.44
ultrasonic force microscopy
UFM
⟨AFM⟩ an **AFM** mode in which an ultrasonic wave is injected through the **probe** to observe the surface or sub-surface mechanical structure

5 Acronyms and terms for contact mechanics models

5.1 In contact mechanics, the basic theories are often referenced by acronyms. To avoid confusion, these acronyms are defined below. These models all assume that the materials in contact are homogeneous and isotropic, and have a linear elastic constitutive behaviour. Various contact models for inhomogeneous, anisotropic, non-linear, viscoelastic, elasto-plastic and other materials have been derived and can be found in the literature.

5.2
BCP
Burnham-Colton-Pollock model
semi-empirical model of **tip** and surface contact that assumes that long-range forces act only outside the contact area[1]

NOTE This simple semi-empirical approach matches many experimental **AFM force-distance curves**. It avoids both the severe discontinuity in the slope of the force curve at contact in **DMT** theory and the adhesion hysteresis of **JKRS** theory. It assumes that long-range forces act only outside the contact area and uses a Hertzian functional relationship between indentation depth and contact radius that gives no adhesion hysteresis.

5.3
COS
Carpick-Ogletree-Salmeron model
model of **tip** and surface contact between a sphere and a flat surface giving a simple general equation that approximates Maugis' solution to within 1 % accuracy[2]

NOTE The general equation is amenable to conventional curve-fitting routines and provides a rapid method of determining the approximate value of the parameter described by Maugis.

5.4
DMT
Derjaguin-Müller-Toporov model
model of **tip** and surface contact in which adhesion forces are taken into account but the tip-sample geometry is constrained to be Hertzian[3]

NOTE This approach applies to rigid systems with low adhesion and small radii of curvature. The adhesion forces are taken into account but the tip-sample geometry is constrained to be **Hertzian**, i.e. Hertzian mechanics with an offset to account for surface forces.

5.5
Hertzian model
model of **tip** and surface contact between elastic solids that ignores any surface forces and adhesion hysteresis

NOTE This approach, derived by Hertz and described by K.L. Johnson[4], describes the contact between elastic solids. It ignores any surface forces and adhesion hysteresis and applies at high loads where there are no surface forces present.

5.6
JKR(S) model
Johnson-Kendall-Roberts (-Sperling) model
model of **tip** and surface contact in which adhesion forces outside the contact area are ignored and elastic stresses at the edge of the contact area are infinite[5]

NOTE 1 In this work, adhesion forces outside the contact area are ignored and elastic stresses at the edge of the contact area are infinite. At contact, short-range attractive forces suddenly operate, and the tip-sample geometry is not constrained to remain **Hertzian**. Adhesion hysteresis is described and loading and unloading are abrupt processes. This approach applies to highly adhesive systems with low **stiffness** and high radii of curvature.

NOTE 2 The JKR and JKRS models are the same. The JKR acronym is very commonly used. The JKRS acronym extends the recognition to Sperling's earlier work[6].

5.7
Maugis model
Maugis-Dugdale model
model of **tip** and surface contact between a sphere and a flat surface incorporating the elastic modulus and **work of adhesion**[7]

NOTE This analysis is a complex mathematical description of the contact mechanics between a sphere and a flat surface which applies in all material possibilities through a parameter that is a function of reduced elastic modulus, reduced curvature radius, work of adhesion and the tip-sample interatomic equilibrium distance. At the limits, when this parameter tends to infinity or zero, the Maugis mechanics tend to the **JKRS** or **DMT** mechanics, respectively.

6 Terms for scanning-probe methods

6.1
Abbe diffraction limit
far-field diffraction limit
⟨NSOM, SNOM⟩ optimum resolution achievable for an optical system, governed by diffraction phenomena, at the limit of collection optics placed at a large number of wavelengths from the object under study

NOTE In classical far-field diffraction theory, the optimum point-to-point resolution observed using a system with a particular **numerical aperture**, **NA**, is given by d, where $d = 0{,}61\lambda/\text{NA}$, in which λ is the wavelength of the illuminating light. With a carefully defined illumination, the factor 0,61 can be reduced to as low as 0,36.

6.2
active length
length of the region of the **probe tip** that can come into contact with the sample in a scan

[ASTM E1813-96[8]]

NOTE 1 This length is set by the height of the tallest feature encountered.

NOTE 2 This length should be less than the **probe length**.

6.3
amplitude modulation detection
AM detection
⟨AFM⟩ dynamic mode in which the change in **probe** height required to keep the vibration amplitude of an oscillated **cantilever** constant while it is scanning over the surface is monitored

NOTE 1 The oscillation frequency is usually set close to the **resonance frequency**, where the amplitude changes are strongest.

NOTE 2 The phase shift between the drive and the response can also be monitored and provides information on dissipated energy due to the tip-sample interaction.

NOTE 3 The detected signals can be used in a feedback system to keep one parameter constant.

6.4
anti-Stokes scattering
the **Raman effect** where the emitted photon has higher energy than the incident photon

cf. **Stokes scattering**

6.5
aperture
⟨NSOM, SNOM⟩ hole, typically circular, in an opaque manifold

NOTE Apertures are critical to the performance of optical (light, electron or optical) instruments in defining their imaging or spectral resolution.

6.6
artefact
artifact
unwanted distortion or added feature in measured data arising from lack of idealness of equipment

6.7
atomic corrugation
regular undulations of the atoms on a low-index or vicinal surface of a single crystal, where the undulations are of atomic width or greater and have heights which are a significant fraction of the atomic size

NOTE The corrugations can arise, for example, from the non-uniform distribution of the local density of states (LDOS) and the minimization of the **surface energy** and can change, for example, as a result of changes in the **probe tip** settings, the probe tip itself, the ambient temperature or adsorbed species.

6.8
ballistic electron
electron that travels through a piece of material without significant scattering

NOTE 1 The energy of the electron is greater than that of any other electron in thermal equilibrium in the system.

NOTE 2 The electron's mean free path is larger than the characteristic dimension of the sample in the direction of transport.

6.9
barrier height
magnitude of the potential energy in a region restricting the movement of electrons

NOTE In **STM**, the magnitude of the barrier height is related to the **tip** and substrate **work functions**. In classical mechanics, an electron with an energy less than the barrier height would not be able to penetrate the barrier, whereas in quantum mechanics there is a finite probability that the electron will tunnel across the barrier. In the quantum **tunnelling** of an electron from a metal through a vacuum gap to a metal, the barrier height is the difference between the **Fermi energy** in the first metal and the maximum of the potential distribution in the space between the two metals.

6.10
barrier height, local
potential energy of a **tunnelling barrier** at a specified location

NOTE When an **STM tip** is scanned across a sample, the potential energy can vary with tip position due to chemical inhomogeneities (e.g. impurities) of lower **work function** at or close to the surface.

6.11
barrier height, tunnelling-
magnitude of the potential energy associated with the **tunnelling barrier**

cf. **barrier height**

NOTE In **STM**, the magnitude of the barrier height is related to the **tip** and substrate **work functions**.

6.12
barrier, tunnelling
energy barrier with an associated height (i.e. energy), width (i.e. length) and shape (i.e. profile of energy versus length) across which electrons traverse by quantum-mechanical **tunnelling**

NOTE For electrons with an energy less than the **barrier height**, quantum mechanics dictates that there is a finite probability for the electrons to tunnel across the barrier, whereas classical mechanics would forbid electron transport.

cf. **tunnelling-barrier height**, **tunnelling-barrier width**

6.13
barrier width, tunnelling-
length associated with a potential-energy barrier that electrons traverse by quantum-mechanical **tunnelling**

NOTE When in the **STM** tunnelling regime, the tunnelling-barrier width is equivalent to the **tip**-sample separation. The tunnelling current decreases approximately exponentially with increasing barrier width.

6.14
Bethe-Bouwkamp model
⟨NSOM, SNOM⟩ model by Bethe and by Bouwkamp describing the wavefield for a sub-wavelength **aperture** in an infinite perfectly conducting screen

NOTE 1 This may be a useful approximation for an **aperture** in **NSOM/SNOM**.

NOTE 2 The original model derives from References [9] to [11].

6.15
blind reconstruction
reconstruction estimate of a sample's (or **tip's**) surface topography when the estimate is obtained from a measured **image** without independent knowledge of the tip's (or sample's) surface topography

cf. **dilation**, **erosion**

6.16
bow
distance, measured at right angles, of the centre point of a sample surface from a reference plane defined by three equidistant points on the surface in a circle around that centre with a radius suitable to cover the surface defined

cf. **flatness**, **warp**

NOTE 1 A positive value indicates a surface that is convex and a negative value indicates a surface that is concave.

NOTE 2 This term is applied to surfaces whose out-of-flatness is essentially described as concave or convex, i.e. they have one extremity that is not at the perimeter of the reference plane.

NOTE 3 This term is often applied to wafers where the diameter of the circle might be 6,25 mm less than the wafer diameter.

6.17
Bückle's rule
indentation to less than 10 % of the layer thickness when measuring the layer hardness directly

NOTE 1 This is an empirical rule established for measuring coating hardnesses and has been shown to apply to films greater than about 5 μm in thickness.

NOTE 2 This rule is often applied to the measurement of film moduli.

6.18
cantilever
thin force-sensing support for a **probe tip**, joined to the **cantilever chip** at the end furthest from the probe tip

NOTE Cantilevers are available in a number of shapes ranging from rectangular or diving board to “V” or “A” shapes where the probe tip is near the narrower end.

6.19
cantilever apex
end of the **cantilever** furthest from the cantilever support structure

cf. **probe apex**

6.20
cantilever assembly
micro cantilever
probe assembly
structure comprising the **chip holder**, **chip**, **cantilever** and **probe**

6.21
cantilever back side
cantilever reflex side (deprecated)
cantilever surface opposite to the surface on which the **probe tip** is mounted

cf. **detector side (of a cantilever)**

NOTE The reflex side has the same meaning as the back side but is only applicable to cantilevers with a reflection coating for use with an optical sensor. Reflex side is therefore deprecated.

6.22
capillary force
force exerted on an **AFM cantilever** or similar **probe** due to capillary condensation at the junction between the probe and the surface

6.23
carbon nanotube probe
probe with a carbon nanotube that forms both the **probe shank** and the **probe tip**

NOTE The carbon nanotube is normally supported on a probe-like structure called the **probe support**. The nanotube and the support comprise a **composite probe**.

6.24
characterized length
region of the **probe** that has been measured by a **probe characterizer**

[ASTM E1813-96[8]]

6.25
chemical force
force between atoms or molecular groups on the **probe tip** and atoms or molecular groups on the surface

6.26
chip
cantilever chip
chip substrate
probe chip (deprecated)
small piece, usually of silicon, on which the **cantilever** has been fabricated and to which it is still attached as a convenient supporting structure in the **probe assembly**

6.27
chip holder
structure on which the **chip**, **cantilever** and **probe** are mounted

NOTE The chip holder, chip, cantilever and probe comprise the **probe assembly**.

6.28
closed-loop scanner
scanning system having a function sensor whose output is fed back into the scanning system to improve the accuracy of its settings

NOTE This term often refers to function sensors that relate to position and **scanners** that can then set their x- and y- and, sometimes, z-positions accurately. This is very important since position scanners are often based on piezoelectric components that exhibit significant hysteresis and creep in the absence of closed-loop control.

6.29
coarse-approach device
device that changes the initial **probe** and sample separations by amounts significantly greater than the vertical (z) **scanner** range

NOTE Typical coarse-approach device ranges are 1 mm whereas the z scanner ranges are typically 1 µm to 100 µm. Coarse approaches are often made in steps similar to the z scanner range and are critical for the routine study of samples.

6.30
composite probe
structure at or near the **cantilever apex** including a **probe support** and a superimposed **probe**

NOTE For work where particular probe qualities, such as probe **tip radius**, **probe stiffness** and probe profile are required, a special probe such as a carbon nanotube can be affixed or grown on the end of a larger probe manufactured by traditional silicon foundry methods. This combination forms a composite probe with the larger probe being termed the probe support.

6.31
cone angle
〈NSOM, SNOM〉 angle subtended between the optical-fibre axis and the wall of the **tip** in an optical-fibre **NSOM probe**

cf. **included half-angle**, **cone half-angle**

6.32
constant-current mode
〈STM〉 mode of scanning the **probe tip** over the sample surface at a constant current by adjusting the relative heights of the **probe** and sample so that the current sensed does not change during the scan

6.33
constant-force mode
〈AFM〉 mode of scanning the **probe tip** over the sample surface at a constant **normal force** by adjusting the relative heights of the **probe** and sample so that the force sensed does not change during the scan

6.34
constant-height mode
mode of scanning the **probe tip** over the sample surface at a constant height over the surface during the scan

NOTE The height is constant relative to the instrument, not the sample surface.

6.35
contact mode
〈AFM〉 mode of scanning the **probe tip** over the sample surface, adjusting the relative heights of the **probe** and sample, in which there is always a repulsive force between the probe and the sample

cf. **intermittent contact mode**, **non-contact mode**, **tapping mode**

NOTE This mode can be, for example, either the **constant-height** or **constant-force mode**.

6.36
contour length
〈polymers〉 length of a segment of polymer at maximum extension

6.37
damping
〈AFM〉 mechanical energy dissipated per unit time from a **cantilever** oscillating with constant, maintained, amplitude during **NC-AFM** measurement

cf. **dissipation**

6.38
detector side (of a cantilever)
surface of a **cantilever** facing the detector

cf. **cantilever back side**

NOTE In the usual arrangement, the detector side and the reflex side are the same side of the cantilever.

6.39
dilation
⟨AFM⟩ mathematical morphological operation by which two shapes, A and B, are combined to produce a third shape in accordance with

$$A \oplus B = \bigcup_{\boldsymbol{b} \in B} \left(A + \boldsymbol{b} \right)$$

where

$\oplus$ is the customary symbol for dilation;

A is the set of all points within the first shape;

$\boldsymbol{b}$ is a vector which successively takes the values of all the points within the second shape (B);

$A + \boldsymbol{b} = \{\boldsymbol{a} + \boldsymbol{b} \mid \boldsymbol{a} \in A\}$ is the translation of A by $\boldsymbol{b}$

cf. **erosion**

NOTE 1 Dilation is discussed by J.S. Villarrubia[12]. To the extent that the **tip** scans the sample in contact without compression, twisting or bending, the shape, I, of an **AFM image** is a dilation given by, $I = S \oplus (-T)$, where S and T are the sample and tip shapes, respectively, and $-T = \{-\boldsymbol{t} \mid \boldsymbol{t} \in T\}$.

NOTE 2 Dilation and convolution are both forms of mixing, but they are mathematically different. In some texts, the reader might find the term convolution used incorrectly.

6.40
dip pen nanolithography
a method in which a scanning **tip** is used to transfer specific material onto a substrate surface, via a solvent meniscus, for patterning a substrate at length scales below 100 nm

NOTE 1 Often the tip is an **AFM** tip coated with specific molecules that are to be deposited on the surface in a layer that can be a **monolayer**. In other cases, the material to be deposited could be **nanoparticles**.

NOTE 2 Dip-Pen Nanolithography is a registered trademark of NanoInk Inc.

6.41
dissipation
⟨AFM⟩ energy transfer from the **tip** to the sample during the tip-sample interaction in **NC-AFM**

cf. **damping**

6.42
dither
action, in the dynamic mode, of oscillating the **tip**

6.43
elastic tunnelling
quantum-mechanical **tunnelling** process in which electrons do not lose energy

NOTE The energy in the initial and final states is the same.

6.44
electrostatic force
force generated by electrostatic effects between the **probe tip** and the sample

6.45
erosion
⟨AFM⟩ mathematical morphological operation by which two shapes, A and B, are combined to produce a third shape in accordance with

$$A \ominus B = \bigcap_{\boldsymbol{b} \in B} (A - \boldsymbol{b})$$

where

$\ominus$ is the customary symbol for erosion;

A is the set of all points within the first shape;

$\boldsymbol{b}$ is a vector which successively takes the values of all the points within the second shape (B);

$A - \boldsymbol{b} = \{\boldsymbol{a} - \boldsymbol{b} \mid \boldsymbol{a} \in A\}$ is the translation of A by $-\boldsymbol{b}$

cf. **dilation**

NOTE 1 Erosion is discussed in Reference [12]. To the extent that imaging is appropriately modelled as a **dilation**, erosion can be used to reconstruct a least outer-bound estimate of the sample's shape, S_r, given by $S_r = I \ominus (-T)$, where I and T are the **image** and **tip** shapes, respectively, and $-T = \{-\boldsymbol{t} \mid \boldsymbol{t} \in T\}$.

NOTE 2 Erosion is mathematically different from deconvolution. In some texts, the reader might find the term deconvolution used incorrectly.

6.46
etched tip
probe tip (generated by an etching process)

NOTE This term generally refers to **STM tips** generated by electrochemical etching, but ion sputter etching can also be used for manufacturing STM tips. This term also applies to optical-fibre tips for **NSOM/SNOM**, where etching in hydrofluoric acid is part of the forming process.

6.47
evanescent wave
part of a wave that extends beyond an interface between materials of differing refractive indexes where, in geometrical optics, the incident wave undergoes total internal reflection

NOTE The intensity of evanescent waves decays exponentially with distance from the interface at which they are formed.

6.48
feedback-induced distortion
distortion of a scan trace arising from the inability of a **probe** microscope feedback to maintain close proximity between the **tip** and surface

[ASTM E1813-96[8]]

NOTE This distortion can be caused by scanning too quickly and can change with scan speed and scan direction.

6.49
Fischer pattern
Fischer projection pattern
⟨NSOM, SNOM⟩ patterned layer, typically of aluminium around 50 nm to 200 nm in thickness and typically evaporated on a glass or quartz cover slip on which monodispersed spheres, typically of latex or polystyrene and typically between 150 nm and 1 µm in diameter, have been deposited prior to evaporation and have been removed after evaporation

NOTE The spheres form an almost perfect close-packed array, with row dislocations that are then reproduced in the aluminium layer. Fischer patterns have been found to be useful to practitioners of SNOM and confocal microscopy because they offer nanoscale features of known dimensions for **optical resolution** tests, while the imperfect close-packing allows the identification of the areas imaged by these high-resolution techniques within the field of view available to, and at the lower resolutions available to, a conventional light microscope. Details are given in Reference [13].

6.50
flatness
minimum distance between two parallel planes that contain the surface

cf. **bow**, **warp**

NOTE This term is applied to surfaces whose out-of-flatness is more complex than described by bow and warp in that they have many extremities that are not at the perimeter.

6.51
flexing-induced distortion
distortion of a scan trace arising from flexing of the **probe tip** or **probe shank** during scanning

6.52
fluorescence
⟨NSOM, SNOM⟩ phenomenon in which absorption of light of a given wavelength by a substance is followed by the emission of light at a longer wavelength

6.53
fluorescence quenching
⟨NSOM, SNOM⟩ process that decreases the intensity of **fluorescence** emission

6.54
fluorescence resonant energy transfer
FRET
⟨NSOM, SNOM⟩ **fluorescence** resulting from energy exchange between a donor and acceptor in close proximity

6.55
fluorescent tagging
chemical attachment of a fluorescent molecule to a molecule being studied

NOTE 1 This permits the distribution or motion of the molecule being studied to be analysed optically.

NOTE 2 Fluorescent molecules are called fluorophores.

6.56
force-distance curve
force-displacement curve
force-deflection curve (deprecated)
force-extension curve (deprecated)
⟨AFM⟩ pairs of force and distance values resulting from a mode of operation in which the **probe** is set at a fixed (x, y) position and the **probe tip** is moved towards or away from the surface as the force is measured

NOTE The force is usually monitored using the **cantilever** deflection.

6.57
force sensor
sensor detecting forces applied to the **probe**

6.58
force spectroscopy
FS
measurement of the interaction force between the **probe tip** and the surface as a function of a control parameter such as tip-sample separation or tip-sample bias

6.59
force-volume mode
⟨AFM⟩ mode of scanning the **probe** at an array of $n \times m$ points across the surface, where a **force-distance curve** is acquired at each point in the array

cf. **pulsed-force mode**

6.60
frequency modulation detection
FM detection
⟨AFM⟩ detection mode in **dynamic-mode AFM** where the change in the oscillation frequency is used in imaging and to control the **tip**-surface separation

NOTE This mode was first described in Reference [14].

6.61
friction, dynamic
phenomenon of two solids in contact in which sliding occurs between the solids and in which resistive mechanisms lead to a force in opposition to the applied force that caused the sliding, so leading to the **dissipation** of energy

NOTE 1 If the applied force exceeds the opposing static frictional force, sliding occurs and the friction is dynamic. If not, no sliding occurs and the friction is static. The maximum frictional force in the static regime can exceed the frictional force in the dynamic regime.

NOTE 2 If the surfaces are not isotropic, the frictional force might not be in the opposite direction to the applied force. In dynamic friction, this can lead to movement at an angle to the direction of the applied force.

6.62
friction force
⟨AFM⟩ **lateral force** arising from **friction** generated by the lateral movement between the **probe tip** and the sample

NOTE 1 The lateral force causes torsional bending of the **cantilever** that can be detected on an optical or other sensor.

NOTE 2 Microscopy in this mode is called **frictional-force microscopy** (**FFM**).

6.63
friction, static
phenomenon of two solids in contact in which no movement occurs between the solids and in which resistive mechanisms lead to a force in opposition to the applied force that would, in the absence of friction, cause sliding between the solids

NOTE If the applied force exceeds the opposing frictional force, sliding occurs and the friction is dynamic. If not, no sliding occurs and the friction is static. The maximum frictional force in the static regime can exceed the frictional force in the dynamic regime.

6.64
functionalized probe
functionalized tip
probe tip with specific functional groups

NOTE In general, the functionalization is achieved by grafting a **monolayer** of specific molecules onto the **tip** so that the presence of specific chemical groups on the sample surface can be detected by, for example, a specific attractive force between the chemical groups and the grafted molecules. The functionalization can also be achieved by fabricating the probe tip from material exhibiting such a property. In certain circumstances, unintended functionalization can contribute to measurements where functionalization was otherwise thought to be absent.

6.65
height tracking mode
topography tracking mode
mode in which data are recorded as the **tip** traces a line at a given height above the surface defined by the pre-determined topography

cf. **planar subtraction mode**

NOTE 1 This mode is used to remove the effects of topography in a line scan. Typical data that can be recorded are forces in general (such as **magnetic forces**), patch fields, etc.

NOTE 2 This mode is also referred to as the lift-off mode, lift mode or path mode by different manufacturers.

6.66
Hertzian contact
form of contact between elastic solids only involving elasticity

NOTE Hertzian contact ignores any surface forces and adhesion hysteresis and generally applies at high loads where there are no surface forces present.

6.67
illumination mode
〈NSOM, SNOM〉 mode of operation of an optical scanning-probe instrument in which the optical excitation is limited so as to define the **optical resolution** of the system

NOTE 1 The optical resolution can be defined, for example, by delivery of the optical excitation by an optical fibre.

NOTE 2 This mode is a common operating mode of **aperture** SNOM systems.

6.68
illumination-collection mode
〈NSOM, SNOM〉 mode of operation of an optical scanning-probe instrument in which the optical excitation and the optical response signal to this excitation are carried by the same **probe tip**

NOTE 1 In SNOM, the illumination-collection mode helps avoid loss of resolution due to the drift of excited states or charge carriers that could occur if only one of either the primary exciting radiation or the detected radiation were to be limited to a small near-field region.

NOTE 2 In practice, the optical response is typically photoluminescence and the probe tip is often a drawn optical fibre.

6.69
image
map
two- or three-dimensional representation of the sample surface where the information at each point in the representation, given by a brightness or colour or as a length in a third dimension, is related to the output signal from a detector or processed intensity information from the available software

NOTE Map intensities can be presented in a normalized fashion to have the maximum and minimum signal intensities set at, for example, full white and full black, respectively, or on a colour scale. The contrast scale should be defined.

6.70
included half-angle
cone half-angle
half tip angle (deprecated)
semi-vertical angle (deprecated)
〈of an AFM probe〉 included angle between the **probe** surface and the axis of symmetry for a cone-shaped probe

NOTE For asymmetric probes, the included half-angles in different azimuths are not the same. These included half-angles need to be specified in defined azimuths, usually along and at right angles to the **cantilever** axis.

6.71
inelastic tunnelling
⟨STM⟩ a process involving quantum-mechanical **tunnelling** in which electrons lose energy

6.72
interfacial energy
quotient of the energy required to increase an interfacial area at thermodynamic equilibrium by that area

NOTE This term should more precisely be the areic interfacial energy or the interfacial energy per unit area since the dimensions are those of energy per unit area. However, in the literature, the abbreviated term interfacial energy is in common usage.

6.73
intermittent contact mode
tapping mode
⟨AFM⟩ mode of scanning the **probe** where the probe is operated with a sinusoidal z-displacement modulation such that the **probe tip** makes contact with the sample for a fraction of the sinusoidal cycle

cf. **contact mode**, **non-contact mode**

NOTE 1 In this mode, the change in the amplitude arising from the intermittent contact can be used to control the relative heights of the sample and tip in the scanned **image**.

NOTE 2 TappingMode is a registered trademark of Veeco.

6.74
I-V spectroscopy
⟨STM⟩ a technique in which the **STM tip** is held at a constant position, while the bias voltage, V, is ramped and the **tunnelling** current, I, is measured

NOTE I-V spectroscopy is also known as I/V, I(V) and IV spectroscopy.

6.75
I-Z spectroscopy
⟨STM⟩ a technique in which the **STM tip** is held at a constant bias voltage, while the tip height, Z, is ramped and the **tunnelling** current, I, is measured

NOTE I-Z spectroscopy is also known as I/Z, I(Z) and IZ spectroscopy.

6.76
Kelvin probe
probe designed to measure the relative potential between the surface and a conducting **tip** by using the dynamic mode and determining the **tip bias** for a null alternating current

NOTE Kelvin probes operate without contact.

6.77
lateral force
⟨AFM⟩ force applied to the **probe tip** in a direction in the surface plane and at right angles to the **cantilever**

NOTE In **AFMs**, the lateral direction is in the plane of the surface and the vertical direction is in the plane normal to the surface. In practice, of course, the **SPM** can be mounted so that the surface normal is horizontal and it should be remembered that these terms refer to the surface plane and not the laboratory floor plane.

6.78
lateral spring constant
k_x, k_y
probe lateral stiffness (deprecated)
quotient of the applied **lateral force** on a **cantilever** at the **probe tip** position on the cantilever by the lateral deflection of the cantilever at that position

cf. **normal spring constant**, **torsional spring constant**

NOTE 1 The symbols k_x and k_y refer to the lateral spring constants for lateral motion at right angles to and along the cantilever axis, respectively.

NOTE 2 In **lateral-force microscopy**, it is the torsional spring constant and not the lateral spring constant that is usually required for interpreting measurements.

6.79
linker molecule
tether (deprecated)
molecule that attaches a target molecule or particle to a surface with a chemical bond

6.80
magnetic force
force acting between magnetic dipoles in a magnetic field

NOTE In **SPM**, the magnetic dipoles are usually incorporated as ferromagnetic material in the **probe tip** and it is the magnetic field of the sample that is measured.

6.81
meniscus force
force between **tip** and sample arising from the presence of a condensed liquid layer in contact with both the tip and the sample

6.82
molecular pulling
force pulling
application of a tensile force to a molecule attached to a second molecule, a particle or a surface to measure bond strength or folding properties

6.83
multi-frequency mode
dual AC mode
a method in which more than one frequency oscillation is applied to an **AFM cantilever**

NOTE The frequency or frequencies are usually harmonics of the fundamental frequency used.

6.84
nano-antenna
⟨NSOM, SNOM⟩ antenna of nanoscopic dimensions which couples light from the far field to the **near field** and/or *vice versa*

NOTE The nano-antenna may be a metal **tip** or an antenna structure defined on an **SPM probe** using lithography or **FIB** processing.

6.85
nanoindentation
indentation of a surface where the indentation depth or the depth of the plastic deformation is less than 100 nm

6.86
nanomechanics
mechanical analysis of materials where significant inhomogeneity in the force or stress field occurs with scales less than 100 nm

NOTE This term applies equally to a number of widely differing situations, including materials with internal inhomogeneities of less than 100 nm, materials probed mechanically with **probes** smaller than 100 nm and single molecules being unravelled.

6.87
nanoparticle
particle with one or more dimensions of the order of 100 nm or less

6.88
near field
⟨NSOM, SNOM⟩ region closer than about one wavelength to a source of electromagnetic radiation, typically light

NOTE 1 For a Hertzian dipole, in the near field the magnetic field is proportional to r^{-3}, while the near-field electric field is proportional to r^{-2}, where r is the distance from the dipole. In the far field, where r is very much larger than one wavelength, both electric and magnetic fields exhibit r^{-1} behaviour. Therefore, sufficiently close to a light source of sub-wavelength dimensions, the electric and magnetic field strengths are dominated by their near-field components.

NOTE 2 As a consequence of Note 1, there is the potential for more information to be acquired by sampling the near field than can be obtained from far-field measurements or imaging, beyond simply improving **optical resolution**.

6.89
near-field Raman microscopy
⟨NSOM, SNOM⟩ acquisition of Raman spectra from a defined small region following excitation of a sample using a near-field optical source

cf. **apertureless Raman microscopy**

6.90
non-contact mode
⟨AFM⟩ mode of scanning the **probe** in which there is always an attractive force between the probe and the sample

cf. **contact mode**, **intermittent contact mode**, **tapping mode**

NOTE 1 This mode can be, for example, the **constant-height** or **constant-force mode**.

NOTE 2 The spatial resolution in **AFM** in the static non-contact mode is generally much poorer than in the contact mode.

NOTE 3 AFM in the dynamic or frequency-modulated (FM) non-contact mode under ultra-high-vacuum conditions is able to achieve atomic resolution.

6.91
normal force
⟨AFM⟩ applied force on the **probe tip** normal to the surface

NOTE Depending on the circumstances, this force can be the force normal to the average surface or the force normal to a small element of that surface.

6.92
normal spring constant
spring constant
force constant
cantilever stiffness (deprecated)
k_z
⟨AFM⟩ quotient of the applied **normal force** at the **probe tip** by the deflection of the **cantilever** in that direction at the probe tip position

cf. **lateral spring constant**, **torsional spring constant**

NOTE 1 The normal spring constant is usually referred to as the spring constant. The full term is used when it is necessary to distinguish it from the lateral spring constant.

NOTE 2 The force is applied normal to the plane of the cantilever to compute or measure the normal force constant, k_z. In application, the cantilever in **AFM** can be tilted at an angle, θ, to the plane of the sample surface and the plane normal to the direction of approach of the tip to the sample. This angle is important in applying the normal spring constant in AFM studies.

6.93
numerical aperture
NA
⟨NSOM, SNOM⟩ product of the refractive index of the medium in which the lens is working, n, and the sine of one-half of the angular aperture of the lens, θ

NOTE 1 The numerical aperture is given by NA = $n\sin\theta$, where 2θ is the full angular aperture of the lens.

NOTE 2 Most optical lenses are operated in air, which has a refractive index of little more than unity. However, operation in immersion oils, which have a considerably higher refractive index, sometimes even up to about 1,56, provides superior resolution.

6.94
optical resolution
⟨NSOM, SNOM⟩ spatial resolution of an optical instrument

6.95
patch charge force
force between two surfaces arising from the electrostatic attraction or repulsion between **surface patch charges**

NOTE Patch charge force is discussed in Reference [15].

6.96
phase contrast
⟨AFM⟩ contrast in **phase imaging**

6.97
phase imaging
imaging using the phase difference between the applied signal for the sinusoidal force or position modulation and the measured signal for the sinusoidal force or position modulation

NOTE The definition of phase imaging for **SPM** given in this part of ISO 18115 is very different from, and should not be confused with, that relevant to optical or electron microscopy.

6.98
photobleaching
loss of optical **fluorescence** in a fluorescent molecule

6.99
piezo force
⟨AFM⟩ contact-mode **AFM** in which electrical contact is made via a conductive **tip** to a piezoelectric sample surface, the response of which to the applied electric field is a displacement that is measured via the AFM **cantilever** tip deflection

6.100
piezoelectric force
force between the **probe tip** and the sample generated by the piezoelectric effect

NOTE This term is not commonly used except to describe the degree to which a **piezoelectric material** can move a mass or load. It is also used to describe the way in which piezoelectric displacement deflects an **AFM cantilever**, which has a well-defined mechanical **stiffness**.

6.101
piezoelectric material
material with a non-centro-symmetric unit cell such that, under an externally applied mechanical stress, an electrical charge is produced across the faces of the material

NOTE Conversely, an externally applied electrical field produces mechanical strain in the sample. Piezoelectric materials are used as sensors and actuators. Piezoelectricity is the generation of electricity as a result of a mechanical pressure. Mechanical strain in crystals belonging to certain classes produces electrical **polarization**, the polarization being proportional to the strain and changing sign with that strain.

6.102
piezoelectric sensor (cantilever)
sensor (cantilever) utilizing the piezoelectric effect for transduction

NOTE These sensors usually convert mechanical stress to electrical charge.

6.103
piezoresistive
material property in which a mechanical stress or strain-induced stress produces a change in the resistance of the material

NOTE Although most materials are piezoresistive, silicon is known for being highly piezoresistive when appropriately doped.

6.104
piezoresistive cantilever
cantilever made of, or including, a **piezoresistive** material or region

NOTE These cantilevers, typically of doped Si, can be used in resistive bridges in order to determine stress or strain.

6.105
pile-up
flow of material around an indenting **probe** leading to a build-up of excess material around the rim of the indent

6.106
pitch
mean distance between corresponding features in a regular array of features on a surface

6.107
planar subtraction mode
mode in which data are recorded as the **tip** traces at a given height above a plane defined by a least-squares fit through the pre-determined topography

cf. **height tracking mode**, **topography tracking mode**

NOTE 1 This approximate mode is used to remove the effects of topography from an **image**. Typical data that can be recorded are forces in general (such as magnetic forces), **patch fields**, etc.

NOTE 2 This mode is also known as planar subtract mode.

6.108
polarization
electric dipole moment per unit volume

NOTE The polarization, P_i, is related to electric displacement, D, through the linear expression $D_i = P_i + \varepsilon_0 E_i$, where ε_0 (usually called the permittivity of free space) equals 8,854 × 10^{-12} coulombs/volt metre and E_i is the electric field.

6.109
probe
structure at or near the end or apex of the **cantilever** designed to carry the **probe tip**

cf. **composite probe**

6.110
probe characterizer
tip characterizer
structure designed to allow extraction of the **probe tip** shape from a scan of the characterizer

[ASTM E1813-96[8]]

6.111
probe flank
side of the **probe** in the region between the **probe apex** and the **probe support** or, if there is no probe support, the **cantilever**

6.112
probe length
distance between the **probe apex** and the **probe support** or, if there is no probe support, the **cantilever**

6.113
probe shank
structure between the **probe apex** and the **probe support** or, if there is no probe support, the **cantilever**

NOTE 1 For a **composite probe**, such as a **carbon nanotube probe**, focused ion beam machined probe or electron beam deposition probe, this term is applied to the fine structure produced on the probe support to analyse the sample. The shank of the probe support is called the **probe support shank**.

NOTE 2 For a **probe** with a higher aspect ratio portion nearer to the probe apex than the portion closer to the cantilever, fabricated by a process such as oxide sharpening, this term is applied to the nanostructure of the probe near the apex. This is typically within a few hundred nanometres of the **tip** end. In this example, the single material of the probe has been engineered into two parts: the probe and the probe support.

6.114
probe stiffness
resistance of the **probe** to flexing caused by **lateral forces**, expressed as a **force constant** describing the lateral flexing of the probe under an impressed force

[ASTM E1813-96[8]]

6.115
probe support
structure at or near the end or apex of the **cantilever** designed to carry the **probe**

NOTE For work where particular probe qualities, such as probe **tip radius**, **probe stiffness** or probe profile, are required, a special probe such as a carbon nanotube can be affixed to or grown on the end of a larger probe manufactured by traditional silicon foundry methods. This combination forms a **composite probe**, with the larger probe being termed the probe support.

6.116
probe support flank
side of the **probe support** in the region between the **probe** and the **cantilever**

6.117
probe support length
length of the **probe support** in the region between the **probe** and the **cantilever**

6.118
probe support shank
structure of the **probe support** in the region between the **probe** and the **cantilever**

6.119
probe tilt angle
angle between the axis of the **probe** and the normal to the plane of the **cantilever**

NOTE The azimuth of the tilt needs to be specified. Where there is no specification, it is assumed that the tilt direction is in the azimuth of the cantilever axis and a positive tilt angle is in the azimuth direction away from the **chip** end and towards the **cantilever apex**.

6.120
probe tip
tip
probe apex
structure at the extremity of a **probe**, the apex of which senses the surface

cf. **cantilever apex**

6.121
protein unfolding
separation of the folds of a protein molecule

NOTE Proteins can fold naturally to lower the system energy. Such proteins, when deposited on a surface, can be mechanically unfolded using an **AFM probe tip** specially functionalized to bond to one end of the protein molecule.

6.122
pulled tip
structure formed by pulling a ductile material, such as a metallic wire or optical fibre, often at elevated temperature, until separation occurs, leaving at least one **tip** with a radius of curvature below 1 µm, and ideally in the range 10 nm to 50 nm

NOTE Pulled tips can be used for imaging by one of the **scanning-probe microscopy** methods, such as **NSOM/SNOM**.

6.123
pull-in force
pull-on force
force exerted by the surface on the **probe tip** at **snap-in**

6.124
pull-off force
force required to pull the **probe** free from the surface

NOTE This force is generally measured from the **force-distance curve** as the value between the force minimum and the zero of force as the probe moves away from the surface.

6.125
pulsed-force mode
mode of scanning the **probe** where the probe is continually undergoing **force-distance curve** cycles at a cycle frequency below the **resonant frequency** of the **cantilever**

cf. **force-volume mode**

NOTE The operating frequency can be in the 100 Hz to 2 000 Hz range, and data for the maximum adhesion force or the sample local **stiffness** can be recorded rather than the whole force-distance curve for each pixel.

6.126
***Q*-control**
electronic feedback system in the **dynamic mode** designed to change the apparent ***Q***-value for an **AFM cantilever**

NOTE 1 This control may be used to raise or lower the Q-factor of a cantilever used in AFM.

NOTE 2 In liquids, the cantilever Q-factor is reduced and so **phase imaging** is degraded. Raising the Q-factor improves the phase imaging quality.

6.127
quality factor
Q
energy stored in a given resonator for a particular resonant peak divided by the average energy lost per radian of oscillation, this average being over one cycle

NOTE 1 The resonator in this context can be, for example, an **AFM cantilever** operating in the **non-contact mode** or an optical-fibre **probe** or tuning fork assembly used with **shear force** sensing in **NSOM/SNOM**.

NOTE 2 A practical method of measuring the quality factor is to record a resonance curve as a function of frequency. It can be shown that Q is approximately equal to the resonant frequency divided by the bandwidth of the resonance, and that this approximation is excellent for quality factors above about 4.

NOTE 3 The bandwidth of the resonance can be measured from a plot of the square of the amplitude against frequency. The bandwidth is the frequency interval between the two points 3 dB below the peak maximum on either side of the peak. This is, to an error of less than 0,25 %, the full width at half maximum height (FWHM) of this curve, so the FWHM can be judged a more convenient and sufficiently accurate measure of bandwidth for many practical purposes.

6.128
Raman effect
⟨NSOM, SNOM⟩ emitted radiation, associated with molecules illuminated with monochromatic radiation, characterized by an energy loss or gain arising from rotational or vibrational excitations

6.129
Raman spectroscopy
⟨NSOM, SNOM⟩ spectroscopy in which the **Raman effect** is used to investigate molecular energy levels

6.130
raster scanning
⟨SPM⟩ two-dimensional pattern generated by the movement of a **probe**

NOTE Commonly used rasters cover square or rectangular areas.

6.131
Rayleigh criterion
⟨NSOM, SNOM⟩ condition where the centre of the Airy disc from one **image** is superimposed on the minimum from another nearby image

NOTE The Rayleigh criterion is usually applied to circular **apertures**, where the criterion for resolution is when the centre of one Airy disc pattern falls on the first minimum of the Airy disc pattern of the second image. The angular separation, θ, is then given by $\theta = 1{,}22\lambda/D$, where λ is the wavelength of light and D is the aperture diameter.

6.132
reconstruction
⟨AFM⟩ estimate of the sample's (or **tip's**) surface topography determined by removing from the **image** the effect of the tip's (or sample's) shape and other measurement **artefacts**

[ASTM E1813-96[8]]

cf. **blind reconstruction**, **dilation**, **erosion**

NOTE 1 Reconstruction is most commonly used to estimate the tip shape when using a **probe characterizer**.

NOTE 2 The estimate can be made by, for example, erosion or erosion with refinements in order to correct the effects of tip or **cantilever** bending or dynamic tip-sample effects.

NOTE 3 This term should not be confused with surface reconstruction, which is concerned with the rearrangement of the atoms on a crystalline surface as a result of annealing or the adsorption of gases, deposited atoms, etc., or as a result of surface relaxation.

6.133
reflection mode
⟨NSOM, SNOM⟩ mode in which the light reflected from the sample is collected as an optical signal

6.134
resonance frequency
natural frequency of resonance of the **probe** and support structure

NOTE The resonance frequency is lower in air than in vacuum, and in water or other liquids it is lower still. The resonance frequency for a probe in contact with a sample may be higher or lower than the resonance frequency in air.

6.135
sample bias
voltage applied to the sample relative to the **probe tip**

6.136
scanner
mechanism that scans the **probe tip** relative to the sample

6.137
scanner creep
slow drift in the position addressed by a **scanner**

NOTE 1 This effect depends on the extent of the excursion of the scanner from its previous position. For scanners without closed-loop control, creep is often in the forward direction and can lead to significant **image** distortion.

NOTE 2 Creep values for piezo tube scanners, without closed-loop control, are given by the ratio of the drift in position to the total change in position used. This ratio is usually expressed as a percentage. The extent of the drift following a change in position, D, can reach an asymptotic value, kD, in the range from 1 % up to 20 % of D, with an exponential time constant, t_0, in the range 10 s to 100 s. Thus, the position at time t becomes $D\{1 + k[1 - \exp(-t/t_0)]\}$.

6.138
scanner hysteresis
difference in position of the **scanner** in a given direction between the forward and backward movements of that scanner

cf. **scanner creep**

NOTE 1 This effect leads to non-linear scans, poor repeatability of **image** registration, image distortion and differences in positioning with scan direction that depends on the extent of the excursion of the scanner from its previous position. Scanner hysteresis can largely be corrected by using a closed-loop feedback system or compensated for, and so reduced, by using appropriate voltage waveforms.

NOTE 2 Hysteresis values for piezo tube scanners, without closed-loop control, are given by the ratio of the maximum of the deviations in position between the forward and reverse scans to the total scan length used. This ratio is usually expressed as a percentage. Typical hysteresis values are in the range up to 20 %. The non-linearity is generally half of this value.

NOTE 3 Scanner hysteresis values are time-dependent and involve **scanner creep**.

6.139
scanning rate
rate of the raster scan driving an **SPM tip**, expressed as the number of lines of the **image** scanned per second or the frequency of repeating the line scan, in hertz

6.140
second harmonic generation
SHG
non-linear effect in which light is scattered with twice the frequency of the incident light

NOTE 1 In **NSOM/SNOM**, **tip enhancement** can lead to second harmonic generation when a metal **tip** is used, or lead to an increase in second harmonic generation from the surface in close proximity to the tip.

NOTE 2 For incident light, the lack of symmetry at a surface or at a buried interface can lead to SHG.

6.141
set point
value of a parameter that an instrument tries to maintain constant when operating in a feedback mode by adjusting the **tip** to sample distance

NOTE When operating an **AFM** in the **contact mode** at constant force, the set point parameter is a force that is sometimes called the set force. In the **dynamic mode**, the set point could be for a vibrational amplitude, frequency or phase.

6.142
sink-in
flow of material around an indenting **probe**, leading to a reduction of material around the rim of the indent

6.143
skin depth
⟨NSOM, SNOM⟩ depth of penetration of the propagating electric field into the metal coating of the optical fibre in a fibre-based **NSOM/SNOM probe**

6.144
snap-in
snap-on
jump to contact (deprecated)
event that occurs when the **tip** is brought close enough to the surface for the force gradient arising from surface attractive forces to exceed the **cantilever** restorative force gradient, causing the tip to spring into contact with the surface

6.145
soft lithography
fabrication or replication of a structure using an elastomeric stamp, mould or conformable photomask

6.146
stiction
phenomenon in which the surface adhesion forces between solids in contact, but unbonded, either exceed the mechanical force designed to separate the solids or significantly affect the separation behaviour

NOTE 1 Stiction occurs in MEMS device manufacture when components are removed from aqueous solutions. It is often overcome using suitable low **surface energy** treatments that can involve **monolayer** adsorption.

NOTE 2 This problem can be studied using **AFM**.

6.147
stiffness
resistance of an elastic material to deflection by an applied force

NOTE The directions of the deflection and the applied force might not be the same. The relationship between these two vectors is characterized by the stiffness matrix.

6.148
Stokes scattering
Raman effect where the emitted photon has lower energy than the incident photon

cf. **anti-Stokes scattering**

6.149
stretching length
amplitude of molecular strain just prior to bond failure

6.150
surface energy
quotient of the energy required to increase a surface area at thermodynamic equilibrium by that increase in area

NOTE 1 This term should more precisely be the areic surface energy or the surface energy per unit area since the dimensions are of energy per unit area. However, in the literature, the abbreviated term surface energy is in common usage.

NOTE 2 This term has no relation to **surface energy approximation** used in EIA (energetic-ion analysis) and RBS (Rutherford backscattering spectrometry).

6.151
surface-enhanced Raman scattering
SERS
enhanced **Raman effect** observed for certain molecules and appropriately prepared metal surfaces, where Raman scattering cross sections are many orders of magnitude greater than for isolated molecules

NOTE The acronym SERS is used for both surface-enhanced Raman scattering and spectroscopy.

6.152
surface-enhanced Raman spectroscopy
SERS
spectroscopy using **surface-enhanced Raman scattering**

NOTE The acronym SERS is used for both surface-enhanced Raman scattering and spectroscopy.

6.153
surface-enhanced resonant Raman scattering
SERRS
surface-enhanced **Raman effect** in which the energy of the incident or scattered radiation is in resonance with an optical transition in the molecule

NOTE The acronym SERRS is used for both surface-enhanced resonant Raman scattering and spectroscopy.

6.154
surface-enhanced resonant Raman spectroscopy
SERRS
spectroscopy using **surface-enhanced resonant Raman scattering**

NOTE The acronym SERRS is used for both surface-enhanced resonant Raman scattering and spectroscopy.

6.155
surface patch charge
local charge arising from variations in the local **work function** of a solid surface

NOTE The surface patch charge arises as a result of variations in the strengths of the surface dipole layer and its associated electrostatic field at the surface (patch field effect). Gauss's law implies that such a field will lead to the appearance of charges at the surface. These variations can arise from regions of a polycrystalline surface having different crystal orientations or from regions with adsorbed layers with different local morphologies or from regions with different local absorbed or adsorbed layers.

6.156
target group
molecular group with specific binding to a defined functional group

6.157
thermal drift
parameter change as a result of the effects of heat or temperature changes

6.158
tilt-compensated probe
⟨AFM⟩ **cantilever** with a **probe** that is tilted with respect to the cantilever plane such that, when mounted, the probe addresses the surface normally

6.159
tip bias
voltage applied to the **tip** measured relative to the sample

6.160
tip enhancement
⟨NSOM, SNOM⟩ enhancement of an optical signal, usually in the **near-field** regime, obtained through the interaction of the electrons at the **tip** end and the illuminating light

cf. **scattering NSOM/SNOM**, **surface-enhanced Raman scattering**

NOTE 1 Enhancements are usually obtained using a metallized **AFM** tip.

NOTE 2 Tip enhancement is important in techniques such as **near-field Raman microscopy**, where some tip materials and structures can lead to surface-enhanced Raman signals many orders of magnitude larger than would otherwise be expected.

6.161
tip radius
⟨excluding scattering NSOM/SNOM⟩ radius describing the surface curvature in a region at the apex of a stylus or **probe tip**

NOTE 1 It might be necessary to describe the tip by radii in different azimuths.

NOTE 2 In practice, tips can only approximate a sphere for a very small region at the tip.

6.162
tip radius
⟨scattering NSOM/SNOM⟩ radius describing a circular region at the **probe tip** from which evanescent light of a significant intensity is emitted

6.163
tip-sample contact radius
maximum radius of the contact area between the **tip** and the sample at the maximum indentation depth

6.164
tip side (of a cantilever)
side of a **cantilever** on which the **probe tip** is mounted

cf. **detector side (of a cantilever)**, **cantilever back side**

6.165
topographic contrast
contrast in a **map** or **image** arising from the topography of the sample surface

NOTE Topographic effects may modify the interaction between the **probe** and the sample, making the interpretation of other data more complex than otherwise.

6.166
torsional spring constant
k_θ
⟨AFM⟩ quotient of the applied torque at the **probe tip** about the **cantilever** axis by the torsional rotation about that axis at the probe tip position

cf. **lateral spring constant**, **normal spring constant**

6.167
transmittance
fraction of incident light that passes through a sample

NOTE The transmittance is usually defined at a specified wavelength.

6.168
tuning fork detection
detection of the **tip**-sample distance using oscillations of amplitude driven by a quartz tuning fork attached to a **cantilever** or optical-fibre **probe**

6.169
tunnelling
quantum-mechanical transport of electrons across a region with a potential energy higher than the electron energy

6.170
tunnelling probability
probability that an electron will traverse the **tunnelling barrier**

NOTE In this quantum-mechanical phenomenon, the tunnelling probability is related to the electron energy, the **barrier height** and the **barrier width**.

6.171
van der Waals force
attractive or repulsive force between molecular entities (or between groups within the same molecular entity) other than those due to bond formation or to the electrostatic interaction of ions or ionic groups with one another or with neutral molecules

[IUPAC[16]]

NOTE The term includes dipole-dipole, dipole-induced dipole and London (instantaneous induced dipole-induced dipole) forces. The term is sometimes used loosely for the totality of non-specific attractive or repulsive intermolecular forces.

6.172
vector scanning
a scanning method that drives the **probe tip** on a defined vector trajectory in the **image** plane

6.173
warp
distance between the upper and lower extremities of a sample surface measured at right angles to a reference plane that is defined either by three equidistant points on the surface in a circle around the centre of the sample surface with a radius suitable to cover the surface defined or by a least squares planar fit to the surface

cf. **bow**, **flatness**

NOTE 1 The method of defining the reference plane should be stated.

NOTE 2 This term is applied to surfaces whose out-of-flatness is more complex than concave or convex, i.e. they have more than one extremity from the reference plane that is not at the perimeter.

6.174
Wollaston wire
wire **probe** comprising an electrically heated platinum **tip** in which the electrical resistance is used to measure the temperature of the tip in order to conduct micro-thermal analysis

6.175
work of adhesion
energy required when two condensed phases, forming an interface of unit area, are separated reversibly to form unit areas of the free surfaces of those two phases

NOTE This term is sometimes also known as the work of separation or the Dupré work of adhesion.

6.176
worm-like chain
⟨polymers⟩ model of the polymer backbone with a continuous, random curvature

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Alphabetical index of terms in this part of ISO 18115

A

Abbe diffraction limit ⟨NSOM, SNOM⟩ 6.1
active length 6.2
AFM 4.3
AM detection ⟨AFM⟩ 6.3
amplitude modulation detection ⟨AFM⟩ 6.3
angle, cone ⟨NSOM, SNOM⟩ 6.31
angle, cone half- ⟨of an AFM probe⟩ 6.70
angle, half tip ⟨of an AFM probe⟩ (deprecated) 6.70
angle, included half- ⟨of an AFM probe⟩ 6.70
angle, semi-vertical ⟨of an AFM probe⟩ (deprecated) 6.70
ANSOM (deprecated) 4.37
anti-Stokes scattering 6.4
aperture ⟨NSOM, SNOM⟩ 6.5
aperture, numerical ⟨NSOM, SNOM⟩ 6.93
apertureless NSOM (deprecated) 4.37
apertureless Raman microscopy ⟨NSOM, SNOM⟩ 4.2
apertureless SNOM (deprecated) 4.37
apex, probe 6.120
artefact 6.6
artifact 6.6
ASNOM (deprecated) 4.37
assembly, cantilever 6.20
assembly, probe 6.20
atomic corrugation 6.7
atomic-force microscopy 4.3

B

back side, cantilever 6.21
ballistic electron 6.8
barrier height 6.9
barrier height, local 6.10
barrier height, tunnelling- 6.11
barrier, tunnelling 6.12
barrier width, tunnelling- 6.13
BCP 5.2
Bethe-Bouwkamp model ⟨NSOM, SNOM⟩ 6.14
bias, tip 6.159
blind reconstruction 6.15
bow 6.16
Bückle's rule 6.17
Burnham-Colton-Pollock model 5.2

C

CAFM (deprecated) 4.5
C-AFM (deprecated) 4.5
cantilever 6.18
cantilever apex 6.19
cantilever assembly 6.20
cantilever back side 6.21
cantilever chip 6.26
cantilever reflex side (deprecated) 6.21
cantilever stiffness ⟨AFM⟩ (deprecated) 6.92
capillary force 6.22
carbon nanotube probe 6.23
Carpick-Ogletree-Salmeron model 5.3
CFM 4.4
characterized length 6.24
charge, surface patch 6.155
chemical force 6.25
chemical-force microscopy 4.4
chip 6.26
chip holder 6.27
chip substrate 6.26
CITS ⟨STM⟩ 4.6
closed-loop scanner 6.28
coarse-approach device 6.29
composite probe 6.30
conductive-probe atomic-force microscopy ⟨AFM⟩ 4.5
cone angle ⟨NSOM, SNOM⟩ 6.31
cone half-angle ⟨of an AFM probe⟩ 6.70
constant-current mode ⟨STM⟩ 6.32
constant-force mode ⟨AFM⟩ 6.33
constant-height mode 6.34
contact mode ⟨AFM⟩ 6.35
contact, Hertzian 6.66
contour length ⟨polymers⟩ 6.36
corrugation, atomic 6.7
COS 5.3
CPAFM 4.5
current-imaging tunnelling spectroscopy ⟨STM⟩ 4.6

D

damping ⟨AFM⟩ 6.37
Derjaguin-Müller-Toporov model 5.4
detector side (of a cantilever) 6.38
DFM ⟨AFM⟩ 4.7
diffraction limit, Abbe ⟨NSOM, SNOM⟩ 6.1
diffraction limit, far-field ⟨NSOM, SNOM⟩ 6.1
dilation ⟨AFM⟩ 6.39
dip pen nanolithography 6.40
dissipation ⟨AFM⟩ 6.41
distortion, feedback-induced 6.48
distortion, flexing-induced 6.51
dither 6.42
DMT 5.4
drift, thermal 6.157
dual AC mode 6.83
dynamic-force microscopy ⟨AFM⟩ 4.7
dynamic friction 6.61
dynamic-mode AFM ⟨AFM⟩ 4.7

E

EC-AFM ⟨AFM⟩ 4.9
EC-STM ⟨STM⟩ 4.10
EFM ⟨AFM⟩ 4.8
elastic tunnelling 6.43
electric-force microscopy ⟨AFM⟩ (deprecated) 4.8
electrochemical atomic-force microscopy ⟨AFM⟩ 4.9
electrochemical scanning tunnelling microscopy 4.10
electron, ballistic 6.8
electrostatic force 6.44
electrostatic-force microscopy ⟨AFM⟩ 4.8
energy, interfacial 6.72
energy, surface 6.150
erosion ⟨AFM⟩ 6.45
etched tip 6.46
evanescent wave 6.47

