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Surface chemical analysis — Scanning-probe microscopy — Determination of cantilever normal spring constants

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A list of organizations represented on this committee can be obtained on request to its secretary.

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Surface chemical analysis — Scanning-probe microscopy — Determination of cantilever normal spring constants

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Foreword

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

The committee responsible for this document is ISO/TC 201, *Surface chemical analysis*, Subcommittee SC 9, *Scanning probe microscopy*.

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Introduction

Atomic force microscopy (AFM) is a mode of scanning probe microscopy (SPM) used to image surfaces by mechanically scanning a probe over the surface in which the deflection of a sharp tip sensing the surface forces mounted on a compliant cantilever is monitored. It can provide amongst other data, topographic, mechanical, chemical, and electro-magnetic information about a surface depending on the mode of operation and the property of the tip. Accurate force measurements are needed for a wide variety of applications, from measuring the unbinding force of protein and other molecules to determining the elastic modulus of materials, such as organics and polymers at surfaces. For such force measurements, the value of the AFM cantilever normal spring constant, k_z, is required. The manufacturers' nominal values of k_z have been found to be up to a factor of three in error, therefore practical methods to calibrate k_z are required.

This International Standard describes five of the simplest methods in three categories for the determination of normal spring constants for atomic force microscope cantilevers. The methods are in one of the three categories of dimensional, static experimental, and dynamic experimental methods. The method chosen depends on the purpose and convenience to the analyst. Many other methods may also be found in the literature.

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INTERNATIONAL STANDARD ISO 11775:2015(E)

Surface chemical analysis — Scanning-probe microscopy — Determination of cantilever normal spring constants

1 Scope

This International Standard describes five of the methods for the determination of normal spring constants for atomic force microscope cantilevers to an accuracy of 5 % to 10 %. Each method is in one of the three categories of dimensional, static experimental, and dynamic experimental methods. The method chosen depends on the purpose, convenience, and instrumentation available to the analyst. For accuracies better than 5 % to 10 %, more sophisticated methods not described here are required.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 18115-2, *Surface chemical analysis — Vocabulary — Part 2: Terms used in scanning-probe microscopy*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 18115-2 and the following apply.

3.1
normal spring constant
spring constant
force constant
DEPRECATED: cantilever stiffness
k_z
<AFM> quotient of the applied normal force at the *probe tip* (3.2) by the deflection of the cantilever in that direction at the probe tip position

Note 1 to entry: See lateral spring constant, torsional spring constant.

Note 2 to entry: 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 3 to entry: 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 an AFM may 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.

3.2
probe tip
tip
probe apex
structure at the extremity of a probe, the apex of which senses the surface

Note 1 to entry: See *cantilever apex* (3.3).

3.3
cantilever apex
end of the cantilever furthest from the cantilever support structure

Note 1 to entry: See *probe apex* (3.2), *tip apex* (3.2).

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4 Symbols and abbreviated terms

In the list of abbreviated terms below, note that the final "M", given as "Microscopy", may be taken equally as "Microscope" depending on the context. The abbreviated terms are:

AFM Atomic force microscopy

FEA Finite element analysis

PSD Power spectral density

SEM Scanning electron microscopy

SPM Scanning probe microscopy

The symbols for use in the formulae and as abbreviated terms in the text are:

A amplitude of cantilever at a certain frequency

A_0 amplitude of a cantilever at its fundamental resonant frequency

A_{white} mean amplitude of a cantilever associated with white noise

B_Φ gradient determined from a straight line fit to values of L_x versus $\Phi_x{}^{1/3}$

B_k gradient determined from a straight line fit to values of L_x versus $\left(k_z^{L_x}\right)^{-1/3}$

C_1 correction factor for the thermal vibration method described in 8.2

C_2 correction factor for the thermal vibration method described in 8.2

d distance between the probe tip and the cantilever apex

D height of the probe tip

e width of the V-shaped cantilever at a distance L_0 from the apex

E Young's modulus of the material of a cantilever

E_B Young's modulus of the base material of a cantilever

E_C Young's modulus of the coating material on a cantilever

f frequency

f_0 fundamental resonant frequency of a cantilever

F force of a nanoindenter

h displacement of a nanoindenter

i index of P_i, where i = 1 to 5

k_B Boltzmann constant

k_z normal spring constant

$k_z^{L_x}$ normal spring constant at the position L_x along a cantilever

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k_z^R normal spring constant of a reference cantilever

k_z^W normal spring constant of a working cantilever

$k_{z(tc=0)}$ normal spring constant of a cantilever with a coating thickness of 0

L length of a rectangular cantilever or the effective length of a V-shaped cantilever

L_x distance between the base of a cantilever and the effective position of a V-shaped cantilever

L_0 length of a V-shaped cantilever between the apex and the start of the arms

L_1 length of a V-shaped cantilever between the base and the start of the arms

P_i label of one of the five positions on the reference cantilever axis

Q quality factor of a cantilever

r term defined by Formula (7)

t thickness of a cantilever

t_B thickness of the bulk material of a cantilever

t_C thickness of a coating on a cantilever

T absolute temperature of the cantilever measured in Kelvins

u_{A0} standard uncertainty in A_0

u_B standard uncertainty in B

u_{C1} standard uncertainty in C_1

u_{C2} standard uncertainty in C_2

u_d standard uncertainty in the distance between the probe tip and the cantilever apex

u_E standard uncertainty in the Young's modulus of a cantilever

u_F standard uncertainty due to the calibration of force in the nanoindenter

u_{f0} standard uncertainty in the resonant frequency

u_h standard uncertainty due to the calibration of displacement in the nanoindenter

u_{kz} standard uncertainty in the normal spring constant

u_{kzR} standard uncertainty in the normal spring constant of the reference cantilever

u_L standard uncertainty in the length of a cantilever

u_Q standard uncertainty in the quality factor of a cantilever

u_t standard uncertainty in the thickness of a cantilever

u_T standard uncertainty in the absolute temperature

u_w standard uncertainty in the width of a cantilever

u_{x1} standard uncertainty in x_1

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