INTERNATIONAL STANDARD

ISO 19606

First edition
2017-02

Fine ceramics (advanced ceramics, advanced technical ceramics) — Test method for surface roughness of fine ceramic films by atomic force microscopy

Céramiques techniques — Méthode d'essai pour la rugosité de surface des films céramique fins par microscopie à force atomique

Reference number
ISO 19606:2017(E)

ISO copyright office
Ch. de Blandonnet 8 • CP 401
CH-1214 Vernier, Geneva, Switzerland
Tel. +41 22 749 01 11
Fax +41 22 749 09 47
copyright@iso.org
www.iso.org

Contents

Page

Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

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 World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see the following URL: www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 206, *Fine ceramics*.

Introduction

Surface roughness measurements of fine ceramic thin films in nanometer scale by atomic force microscopy have become one of the techniques widely applied to quality control and assurance in industries.

One of the problems most frequently occurring in roughness measurements by atomic force microscopy resulting from its scale dependency is the deviation of roughness due to the wear of the probe tip or the deviation in the curvature of commercially available probe tips. This problem makes it difficult to obtain a reliable and reproducible result of the roughness measurement. Therefore, it is highly desirable to standardize a method to evaluate probe tip diameter or curvature radius.

This document covers the evaluation of probe-tip diameter and provides a method to judge the adequateness of a probe tip for use in day-to-day roughness measurements of fine ceramic thin films with a certain arithmetical mean roughness in the range needing the use of atomic force microscopy in production lines or quality assurance processes.

It should be noted that because surface roughness is a scale-dependent metrology parameter, it is unavoidable that the probe-tip evaluation process contains some contradictory procedures, namely the adequateness of the probe tip for a roughness measurement depends on unmeasurable true roughness in a scale of interest.

In this document, the parameters based on roughness profiles are used. The roughness profile is obtained by using a low-pass filter according to ISO 16610-21. The process to obtain the sampling length, which is identical to cut-off wavelength, is given in ISO 4288. Some different sampling lengths to process a primary profile can be applied to obtain appropriate values of arithmetic mean deviation of a roughness profile, if necessary.

Fine ceramics (advanced ceramics, advanced technical ceramics) — Test method for surface roughness of fine ceramic films by atomic force microscopy

1 Scope

This document describes a method to evaluate the adequateness of a probe tip for fine-ceramic thin-film surface roughness measurements by atomic force microscopy, of surfaces with an arithmetical mean roughness, *Ra*, in the range of about 1 nm to 30 nm and a mean width of roughness profile elements, *RSm*, in the range of about 0,04 µm to 2,5 µm.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 4287, *Geometrical Product Specifications (GPS) — Surface texture: Profile method — Terms, definitions and surface texture parameters*

ISO 4288, *Geometrical Product Specifications (GPS) — Surface texture: Profile method — Rules and procedures for the assessment of surface texture*

ISO 11039, *Surface chemical analysis — Scanning-probe microscopy — Measurement of drift rate*

ISO 11952, *Surface chemical analysis — Scanning-probe microscopy — Determination of geometric quantities using SPM: Calibration of measuring systems*

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

ISO 25178-2, *Geometrical product specifications (GPS) — Surface texture: Areal — Part 2: Terms, definitions and surface texture parameters*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 4287, ISO 4288, ISO 18115-2, ISO 11039, ISO 11952 and ISO 25178-2 and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— IEC Electropedia: available at http://www.electropedia.org/

— ISO Online browsing platform: available at http://www.iso.org/obp

3.1
evaluation length
ln(X), *ln(Y)*
length of surface profile in the *X* or *Y* direction

3.2
probe-tip diameter evaluation standard plate
plate on which needle-shaped spikes are formed

Note 1 to entry: The plate is used to evaluate the *probe-tip diameter* (3.3).

3.3
probe-tip diameter

D

diameter of a probe tip at a distance of 10 nm from the tip end

4 Test environment

Testing shall be carried out only where temperature change, sound noise and mechanical vibration of the floor or walls are small enough to perform the measurements. The following installation environment is recommended:

a) temperature: 18 °C to 25 °C;

b) humidity: 70 % or less;

c) noise level: 60 dB or less;

d) mechanical vibration of the floor or the wall: 1×10^{-3} m/s^2 (<100 Hz) or less.

5 Roughness measurement specimens

Specimens for roughness measurements are ceramic thin films on a substrate. Any kinds of substrate material can be used, such as metal, glass, polymer, etc. The specimen shall be no larger than the specimen stage of the instrument being used.

6 Test apparatus

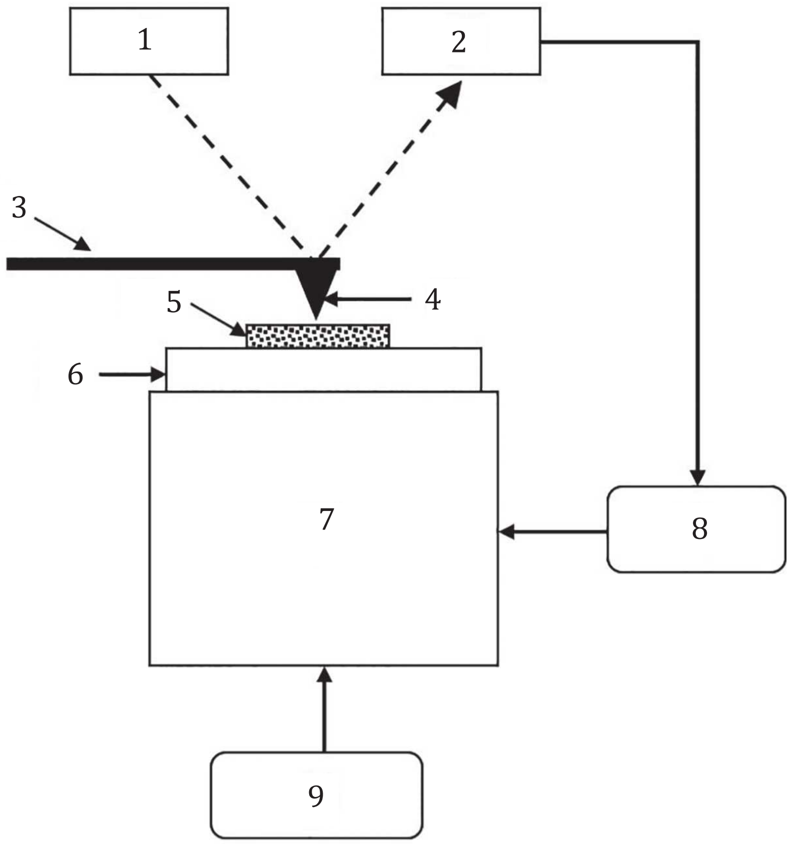
6.1 Cantilever

The cantilever shall be exclusively dedicated for a dynamic mode and commercially available. The resonant frequency should be higher than 100 kHz.

6.2 Scanner

The scanner shall be capable of scanning cantilever or specimen stage by shifting the *XYZ* position. The scanning area should be larger than 10 μm × 10 μm in the *XY* plane.

Figure 1 shows an example of a measurement system having a specimen stage scan mechanism. Position in the *Z* direction is controlled using a *Z*-position control circuit that keeps a constant separation between the probe and the specimen surface. For this purpose, a light beam from a laser diode illuminates the cantilever and the reflected beam position is monitored by a light detector. Surface profile is measured by scanning the specimen stage in the *XY* plane.



Key

1	laser diode	6	specimen stage
2	light detector	7	*X*, *Y* and *Z* scanner
3	cantilever	8	*Z*-position control circuit
4	probe tip	9	*X*-*Y* scan circuit
5	specimen		

Figure 1 — Schematic of AFM system

6.3 Specimen stage

The specimen stage shall be capable of supporting a specimen horizontally. The test area of the specimen should be in the centre of the specimen stage. Scanning should be performed near the centre of the *X*, *Y* and *Z* axes of the scanner used.

7 Test apparatus calibration

This document only describes a method to evaluate the adequateness of a probe tip for fine-ceramic thin-film surface roughness measurements by atomic force microscopy. If the apparatus needs to be calibrated, refer to standards describing calibration criteria and methods for a scanning probe microscope; see ISO 4288, ISO 11039 and ISO 11775.

8 Probe-tip diameter evaluation standard plate

A standard for probe-tip diameter evaluation is a plate on which a number of needle-shaped spikes, arranged in a square matrix, are formed. The needle-shaped spikes are typically as follows:

- tip curvature radius: 10 nm;
- tip aperture angle: 20° or 50°;
- tip height: 300 nm to 600 nm;
- distance between any two nearest neighbour tips: 2,12 µm;
- plate size: 5 mm × 5 mm.

9 Calibration of *X*-*Y* and *Z* scan axes

The calibration of the *X*-*Y* scanner and *Z* scanner should be carried out by measuring the *X*, *Y* and *Z* profile of a certified calibration standard. The standard should have a grating with a certain pitch and a step with a certain height.

The standard sample is a specimen with calibrated height and pitch, which are certified and traceable with uncertainty data attached. It is recommended that the grating pitch is less than 2 µm and that the step height is less than 20 nm.

The calibration standard should be stored in a clean and dry box and be handled with care.

The calibration shall be carried out in the following sequence using the dynamic mode.

a) Mount the calibration standard in such a way that the grating is oriented to the *X*-*Y* axes of the scanner and that its plane lies nearly parallel to the *X*-*Y* plane of the scanner.

b) Set the number of picture elements at 512 × 512 or 256 × 256.

c) Scan an area of about 10 µm square of the calibration standard and store the surface profile data. An example is shown in Figure 2 a).

d) From the surface profile data, draw a surface profile along the *X* direction at a selected *Y* position where the surface profile contains several steps on the calibration standard and level off the one-dimensional profile along the *X* direction. An example is shown in Figure 2 b).

e) Measure profile peak height at the centre of top and bottom sections of the profile. Calculate mean height for at least five successive profile elements in the profile along the *X* direction.

f) Measure a pitch along the *X* direction by measuring the distance between the mid-points of two successive rising or falling parts of the profile.

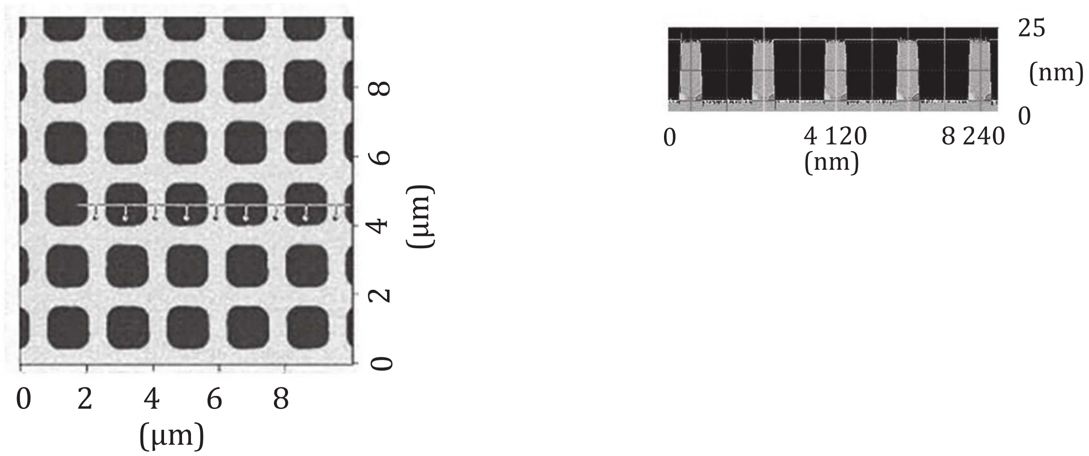
g) From the surface profile data, draw a surface profile along the *Y* direction at a selected *X* position where the surface profile contains several steps and level off the one-dimensional profile along the *Y* direction.

h) Measure profile peak heights at the centre of top and bottom sections of the profile. Calculate mean height for at least five successive profile elements in the profile along the *Y* direction.

i) Measure a pitch along the *Y* direction by measuring the distance between the mid-points of two successive rising or falling parts of the profile.

j) If an *X*- or *Y*-pitch measured is out of the range of uncertainty needed for roughness measurements, correct *X* or *Y* values by obtaining an *X*- or *Y*-axis calibration factor.

k) If the mean height obtained is out of the range of uncertainty needed for roughness measurements, correct *Z* values by obtaining a *Z*-axis calibration factor.



a) Surface profile

b) Surface profile along the *X* direction

Figure 2 — Examples of surface profile data for the calibration of the *X*-*Y* scanner and *Z* scanner

10 Probe-tip error evaluation

10.1 Outline of probe-tip error evaluation

The error for roughness measurements using a probe tip with a certain probe-tip diameter shall be evaluated by using a probe-tip error evaluation template, providing the error from the relationship between the probe-tip diameter, preliminary *Ra* and preliminary *RSm*. If a probe tip is judged to be unsuitable for a roughness measurement with a certain error for a specimen to be measured, it should be rejected and replaced with a new one.

Probe-tip evaluation shall be carried out using the probe-tip evaluation sequence shown in Figure 3.

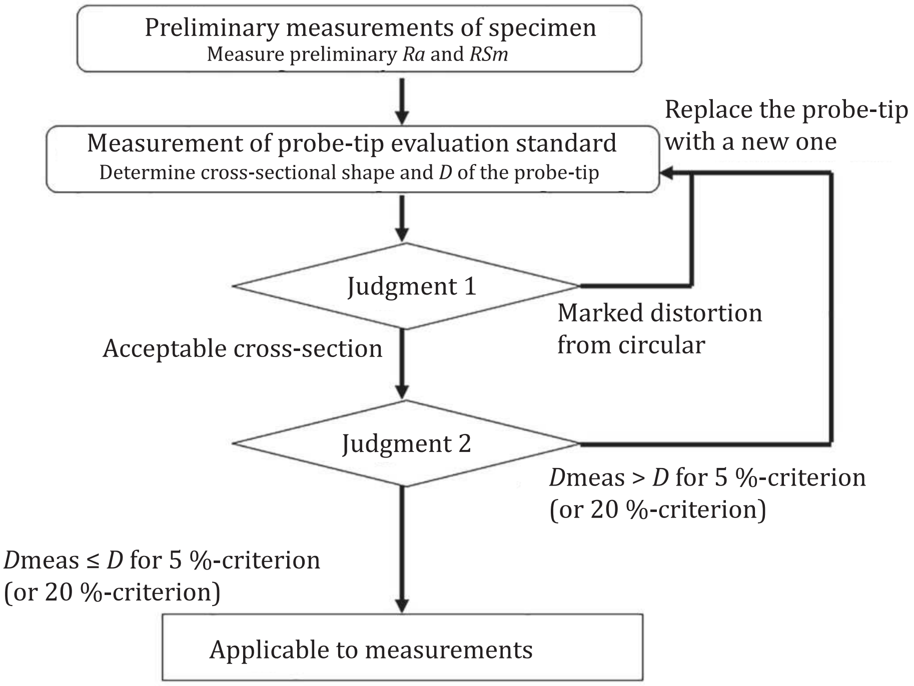


Figure 3 — Probe-tip evaluation sequence

10.2 Measurements of preliminary *Ra* and *RSm*

Preliminary roughness measurements shall be carried out to obtain preliminary *Ra* and *RSm*, the values to be used in the probe-tip judgement procedure.

a) Place the specimen to be measured on the specimen stage without any surface treatment or without using any adhesive.

b) Choose arbitrarily a measuring position on the specimen.

c) Set the number of picture elements at 256 pixels or 512 pixels in the *X* direction and the scanning speed within 0,5 Hz to 1 Hz.

d) Scan a 2 µm line in the *X* direction at a fixed *Y* position using the dynamic mode. Again scan a 10 µm line in the *X* direction at the same *Y* position. Apply an appropriate cut-off length.

e) Select one of the two surface profiles along the *X* direction, such that the number of profile elements in the evaluation length *ln*(*X*) is between 20 and 50.

f) Calculate preliminary *Ra* and *RSm* values from the selected surface profile.

10.3 Evaluation of probe-tip diameter

The evaluation of probe-tip diameter should be carried out using the following sequence. A schematic drawing of probe-tip diameter determination is shown in Figure 4.

a) Measure a part of the probe-tip diameter evaluation standard plate by scanning a 2 µm × 2 µm to 3 µm × 3 µm squared area with the number of picture elements ranging from 128 pixels × 128 pixels to 32 pixels × 32 pixels to identify a needle-shaped spike on the standard plate to be used in a probe-tip diameter measurement.

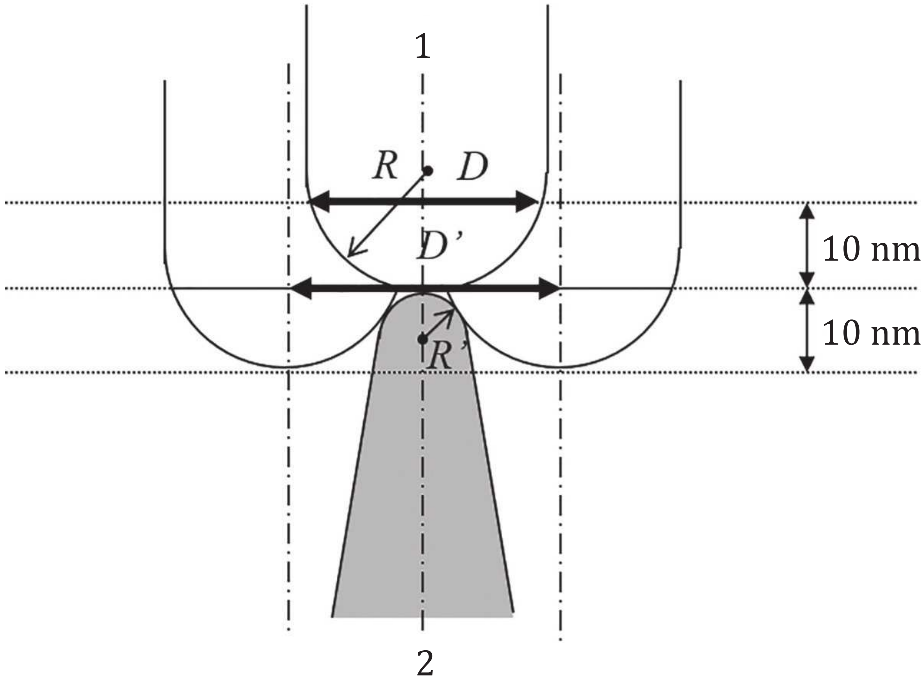
b) Confirm one of needle-shaped spikes on the surface is profiled.

c) Adjust the scanning area so that the centre of the needle-shaped spike lies in the centre of the measured area.

d) Measure again the area under the following conditions: the scan area of 1 × 1 to 1,28 μm × 1,28 μm squared, picture elements of 512 pixels × 512 pixels and a scan speed of 0,5 Hz. Apply an appropriate cut-off length (typically 300 nm to 700 nm).

e) Draw the cross section of the needle-shaped spike profiled at 10 nm below its top in the *Z* direction. An example of such a cross section is shown in Figure 5 b). If the shape is markedly distorted from circular, the probe tip should be rejected and replaced with a new one. The tip-diameter evaluation should be repeated for the new probe tip (Judgment 1). It is recommended to draw a bird's-eye view of the profile as shown in Figure 5 a).

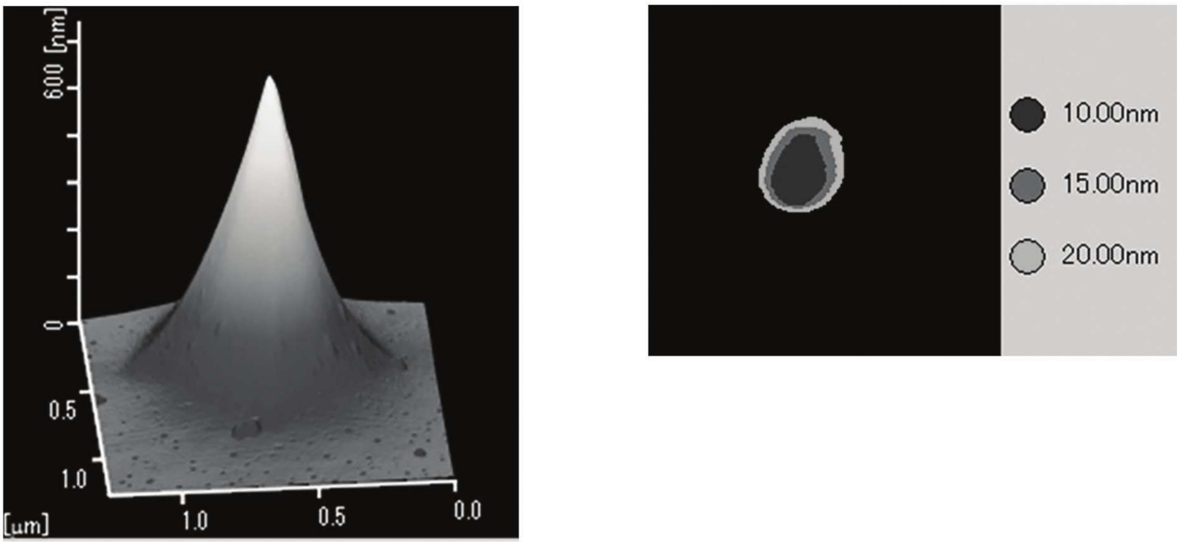
f) If the ratio between the smallest dimension and largest dimension of the cross section drawn in e) is less than a factor of 0,8 then measure another tip. If not then calculate the probe-tip diameter as described in Annex A. For the purposes of the calculation of *D*, assume that the diameter of the cross section drawn in e), *d*, is the average of the smallest and largest dimensions. Regard the calculated diameter as the probe-tip diameter, *D*. The determination of *D* is described in Annex A.



Key

1	probe tip
2	one of the needle-shaped spikes on the probe-tip evaluation standard plate
R	probe-tip curvature radius
R'	curvature radius of a needle-shaped spike
D	probe-tip diameter
D'	characterized probe-tip diameter, the distance between the probe centre at the depth of 10 nm beneath the top of the needle-shaped spike on the probe-tip evaluation standard plate

Figure 4 — Schematic drawing of fundamentals of probe-tip diameter determination



a) Bird's-eye view of measured surface profile **b) Cross section**

Figure 5 — Example of measured data of one of the needle-shaped spikes on the probe-tip diameter evaluation standard plate, diameter, *D*′: 27,3 nm

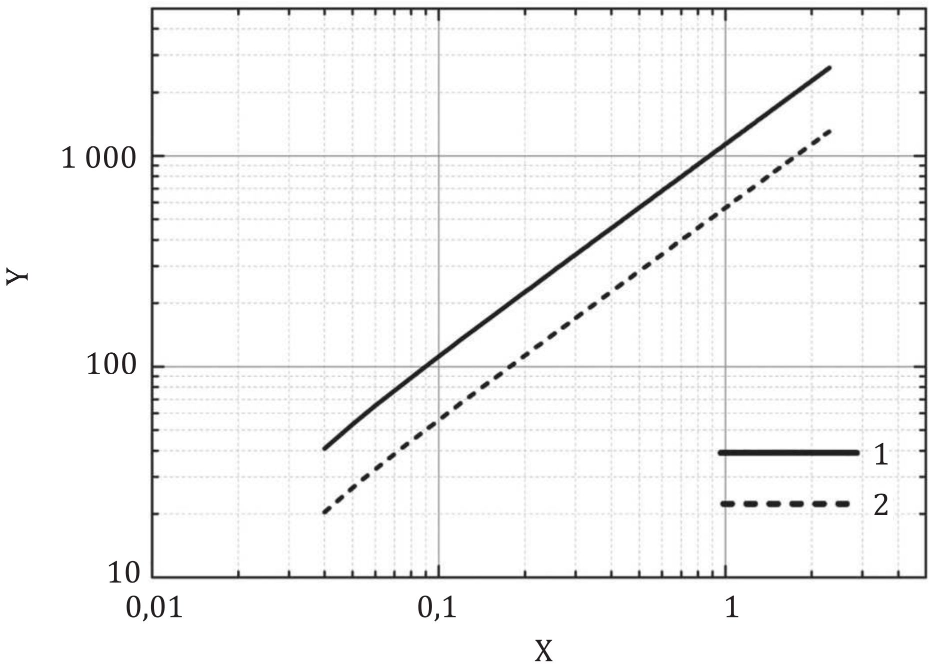
10.4 Evaluation of error in roughness measurements

Judge if the *D* obtained in 10.3 is suitable or not for roughness measurement of a specimen to be measured by applying one of error evaluation templates given in Figures 6 to 9 (Judgment 2).

A 5 %-criterion and a 20 %-criterion are defined, which enable roughness measurements with an error less than 5 % and 20 %, respectively. Fundamental assumptions of the criteria are described in Annex B.

Figure 10 shows how to use the error evaluation templates given in Figures 6 to 9 for the probe-tip error evaluation. For a given rough value of *RSm*, if *D* is placed above the solid line in the *D*-*RSm* map, for example *D* = *D*1, the probe tip is not suitable for roughness measurements of a specimen to be examined because measurement error due to tip diameter exceeds 20 %. If *D* is placed below the solid line, for example *D* = *D*2, the probe tip enables roughness measurements with an error <20 %. If *D* is placed below the dotted line, for example *D* = *D*3, the probe tip enables roughness measurements with an error <5 %. Templates given in Figures 6 to 9 show 5 %-criterion and 20 %-criterion for specimens with *Ra* = 1 nm, 3 nm, 10 nm and 30 nm, respectively. Apply one of the criteria depending on the required accuracy of roughness measurements.

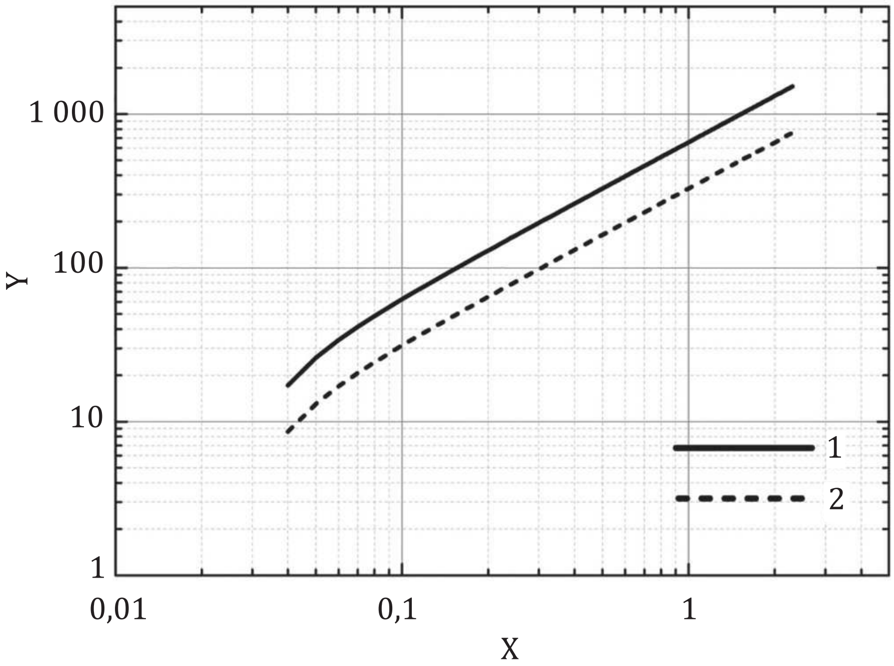
If the probe tip is not applicable for roughness measurement of a specimen with a certain evaluation error, replace the probe tip and evaluate the probe-tip error again by using the procedure described in 10.3.



Key

1	solid line: 20 %-criterion	X	*RSm* in µm
2	dotted line: 5 %-criterion	Y	probe tip diameter in nm

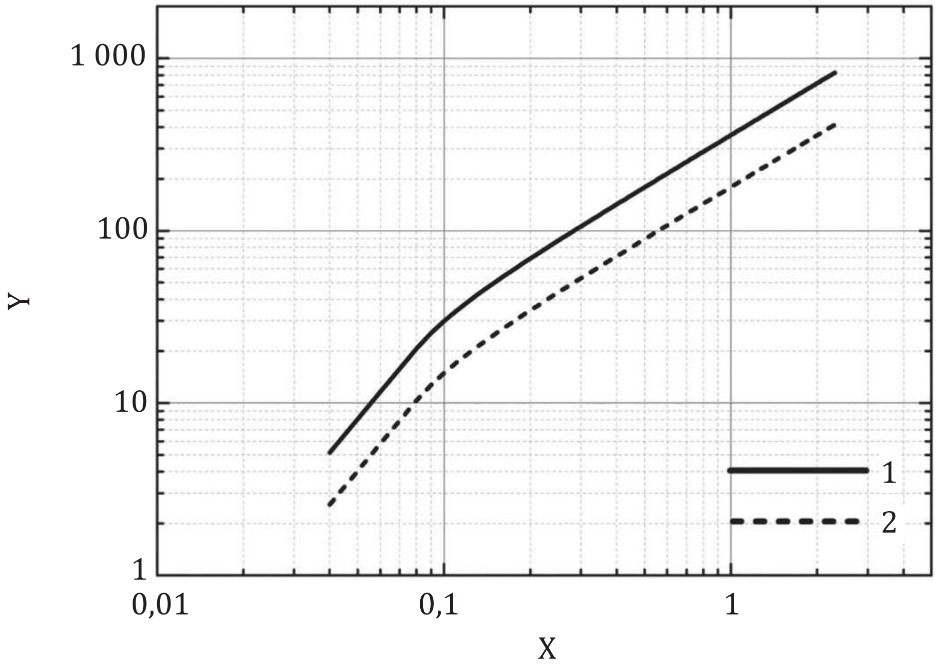
Figure 6 — *D-RSm* map for probe-tip error evaluation to measure roughness of a specimen with preliminary *Ra* of 1 nm



Key

1	solid line: 20 %-criterion	X	*RSm* in µm
2	dotted line: 5 %-criterion	Y	probe tip diameter in nm

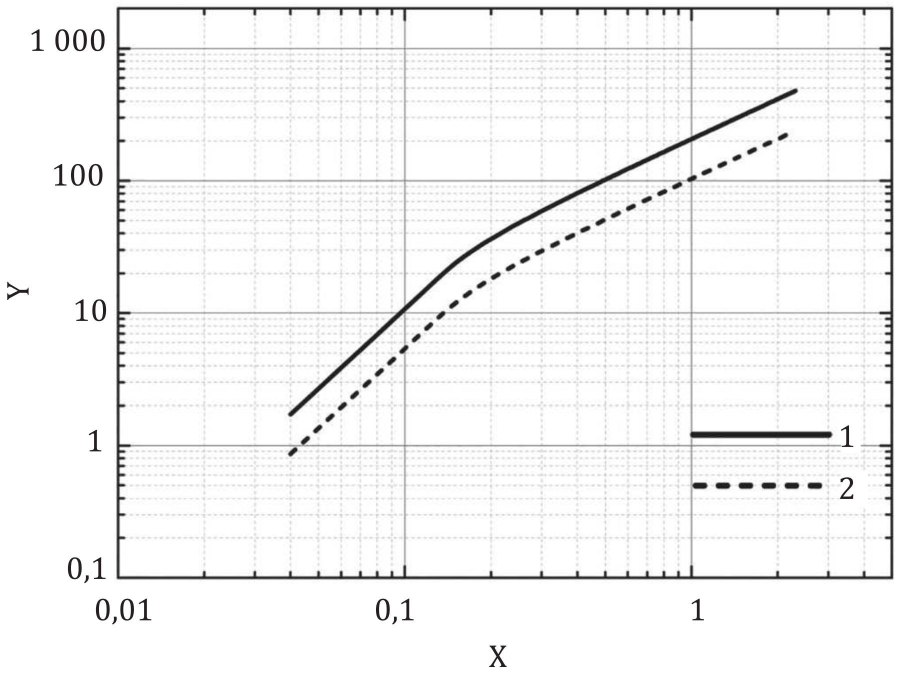
Figure 7 — *D-RSm* map for probe-tip error evaluation to measure roughness of a specimen with preliminary *Ra* of 3 nm



Key

1	solid line: 20 %-criterion	X	*RSm* in µm
2	dotted line: 5 %-criterion	Y	probe tip diameter in nm

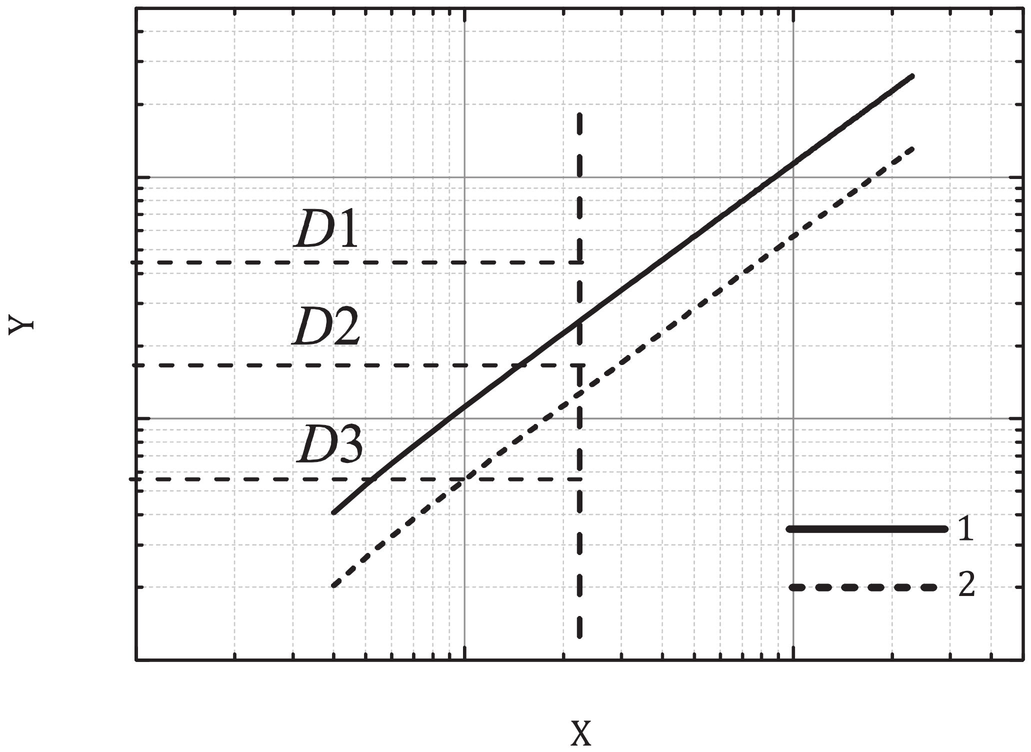
Figure 8 — *D-RSm* map for probe-tip error evaluation to measure roughness of a specimen with preliminary *Ra* of 10 nm



Key

1	solid line: 20 %-criterion	X	*RSm* in µm
2	dotted line: 5 %-criterion	Y	probe tip diameter in nm

Figure 9 — *D-RSm* map for probe-tip error evaluation to measure roughness of a specimen with preliminary *Ra* of 30 nm



Key

1	solid line: 20 %-criterion	X	*RSm*
2	dotted line: 5 %-criterion	Y	probe tip diameter

Figure 10 — *D-RSm* map describing how to apply the templates of Figures 6 to 9 for probe-tip evaluation

11 Roughness measurements of specimen

Roughness measurements shall be carried out using an evaluated probe tip and under the measurement conditions given in Clause 4. The roughness measurement sequence shall be as follows.

a) Mount the specimen to be measured as described in Clause 5.

b) Choose a number of measuring points on the specimen. For example, four corners and the centre of a 10 mm square in the middle area of the specimen as shown in Figure 11.

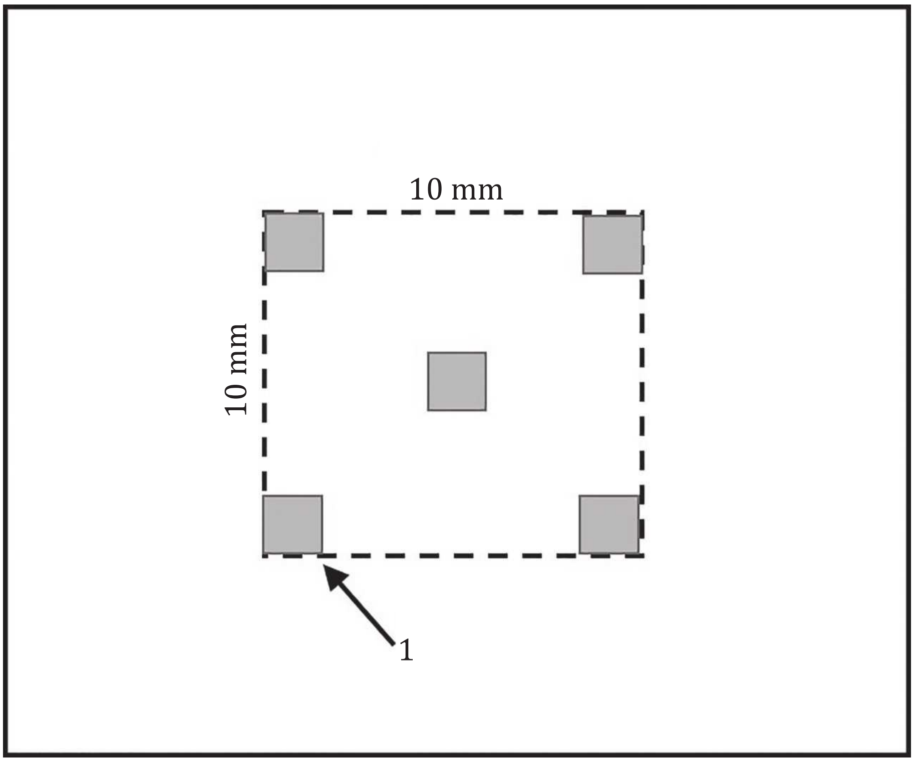
c) Select the number of picture elements from 256 pixels to 512 pixels in the *X* direction and from 10 pixels to 512 pixels in the *Y* direction. Evaluation lengths *ln(X)* and *ln(Y)* are chosen so as to contain 20 periods to 50 periods of the profile elements. Apply an appropriate cut-off length to suppress a long-wave component. Table 1 shows the recommended evaluation lengths for each preliminary *RSm* value of the specimen. Pixels in the *Y* direction could be 10 pixels if the average roughness of a line profile is measured.

d) Scan the surface of the specimen at the given conditions.

e) Repeat the evaluation of the probe-tip diameter, *D*, when, during a series of roughness measurements, a change in image is observed that could be due to wear of the probe tip. If the change in the probe-tip diameter is confirmed by the probe-tip diameter evaluation, the roughness measurement conditions should be reconsidered.

f) Calculate *Ra* or *Sa* of the specimen using numerical data of the surface profile after compensating for any specimen tilt from the horizontal.

g) Obtain *Rz* or *Sz* of the specimen using numerical data of the roughness profile after compensating for any specimen tilt from the horizontal by referring to ISO 25178-2 and ISO 25178-3 (*Rz* is maximum height of the profile and *Sz* is maximum height of the surface).



Key

1 measuring points

Figure 11 — Measuring positions on the specimen: four corners and the centre of a 10 mm square in the middle area

Table 1 — Recommended evaluation length for roughness measurements

Preliminary ***RSm*** µm	**Recommended evaluation length** *ln* (µm)
0,04 < *RSm* < 0,10	2
0,10 ≤ *RSm* < 0,20	5
0,20 ≤ *RSm* < 0,40	10
0,40 ≤ *RSm* < 1,0	20
1,0 ≤ *RSm* < 2,5	50

12 Test report

The test report shall contain the following items as a minimum:

a) type, material and shape of the test specimens;

b) date of the test, name of person conducting the test, and name and address of the testing establishment;

c) the International Standard used (including its year of publication);

d) manufacturer, model number and specification of the measurement system;

e) type and detailed shapes of probe-tip diameter evaluation standard;

f) manufacturer and number of standard used to calibrate X, Y and Z axes of the instrument;

g) temperature and humidity in the measurement room;

h) test conditions used (material of the probe, model number of cantilever, resonant frequency, vibration frequency, Q value, scanning area, scanning speed, number of picture elements, and kind and shape of specimen holder if used);

i) probe-tip evaluation data (bird's-eye profile data, cross-section data, probe-tip diameter evaluated);

j) test result data (images of roughness measurements and values of Ra or Sa, Rz or Sz, etc.);

k) any deviations from the procedure;

l) any remarks about the testing circumstances;

m) any unusual features observed.

Annex A
(normative)

Determination of *D* from *D’*

A.1 Conditions needed for probe-tip diameter evaluation standard plate

The values of tip curvature radius and tip aperture angle should be obtainable from the supplier.

A.2 Fundamental assumptions

Probe-tip end is spherical with a curvature radius, *R*.

The diameter of the needle-shaped spikes on a probe-tip diameter evaluation standard plate *R’* ranges from 5 nm to 10 nm.

The aperture angle of the needle-shaped spikes on a probe-tip diameter evaluation standard plate ranges from 20° to 50°.

A.3 Procedures

A probe-tip diameter *D* is calculated as a function of *R’* and *D’*.

Using the given values of the curvature radius, *R’*, and *θ*, the value of *D’*, i.e. the diameter of the cross section of the spike drawn in 10.3 e), calculate the curvature radius of the probe tip. The formula used for this calculation depends on the values of the angular aperture of the needle-shaped spike and measured *D’*. There are two cases: $D' \geq D'_{\mathrm{crit}}$ and $D' < D'_{\mathrm{crit}}$, where D'_{crit} is the diameter measured for the radius of the probe tip when, for the conditions shown in Figure 4, contact between it and the needle-shaped spike occurs at the transition point between the curved tip of the spike and its conical base for a certain angular aperture. D'_{crit} is given by Formula (A.1):

$$D'_{\mathrm{crit}} = 2R = 2\frac{10}{1-\sin(\theta/2)}\cos(\theta/2) \tag{A.1}$$

For aperture curvature to be considered in the measurements, D'_{crit} is given for the sake of convenience in Table A.1.

Table A.1 — D'_{crit} for various aperture angles

Aperture angle (°)	20	30	40	50
D'_{crit} (nm)	47,6	52,2	47,2	62,8

For $D' < D'_{\text{crit}}$, use Formula (A.2):

$$D = 2R = 2\left(\frac{D'^2}{40} + 10 - 2R'\right) \tag{A.2}$$

For $D' \geq D'_{\text{crit}}$, use Formula (A.3):

$$D = 2R = \frac{\dfrac{D'}{2} - \dfrac{R'}{\cos(\theta / 2)} + (R' - 10)\tan(\theta / 2)}{[1 - \sin(\theta / 2)]\tan(\theta / 2) + \cos(\theta / 2)} \tag{A.3}$$

where θ is the aperture angle of the needle-shaped spike.

Annex B

(informative)

Method to determine criteria for probe-tip error

B.1 Fundamental assumptions

The desirable D to measure surface roughness with a certain accuracy is calculated using a model shown in Figure B.1 assuming as follows.

a) Surface profile of the specimen $f(x)$ is given by

$$f(x) = \frac{\pi Ra}{2}\cos\left(\frac{2\pi}{RSm}x\right)$$

$$\text{because } Ra = \frac{Rz}{\pi} \qquad \text{(B.1)}$$

This Ra value agrees well with real specimen surfaces compared with that of a triangular- or rectangular-shaped surface because the real surface can be approximated by the sum of cosine curves.

b) The probe-tip has a spherical shape with radius R.

c) The probe-tip shall reach the base of the valleys of the surface. Therefore, the maximum value of tip radius $R_{\max}$ occurs when the spherical face of the probe tip fits the base of the valley of the cosine curve.

B.2 Maximum value of *D*

$R_{\max}$ is obtained using Formula (B.2):

$$R_{\max} = \frac{RSm^2}{2\pi^3 Ra} \qquad \text{(B.2)}$$

Then the maximum D value corresponding to $R_{\max}$ can be determined using Formulae (B.2) and (B.3):

$$D_{\max} = 2(20\,R_{\max} - 100)^{0,5}\ (10\ \text{nm} \le R) \qquad \text{(B.3)}$$

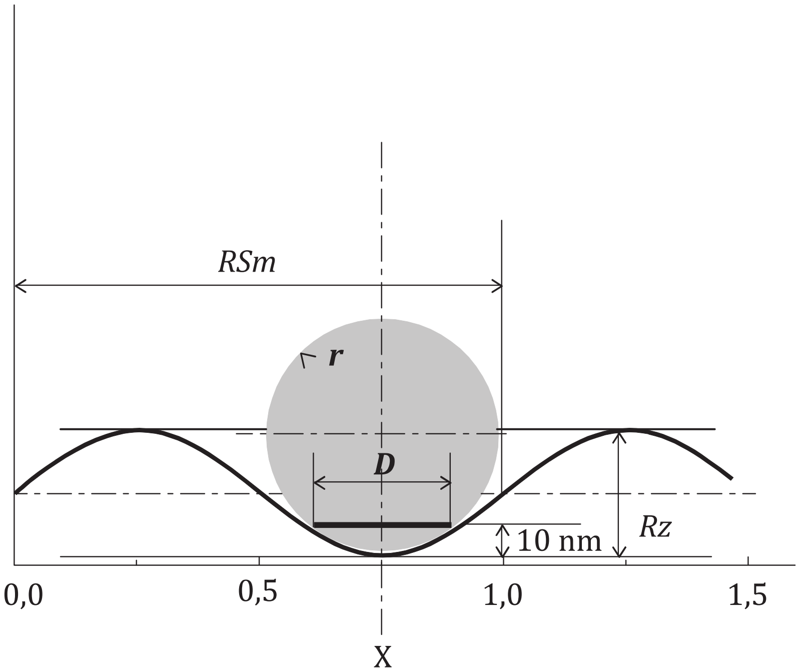
$$D_{\max} = 2\,R_{\max}(R < 10\ \text{nm}) \qquad \text{(B.4)}$$

B.3 Comparison between calculations and measurements

$D_{\max}$ values calculated for specimens with Ra = 5 nm and 20 nm are shown in Figures B.2 and B.3, respectively. Open circles show D for probe tips used for a measurement. Measured Ra and its measurement error (ΔRa) for a specimen with Ra = 5 nm are plotted in Figure B.4. If it is assumed that the measured Ra using the sharpest probe tip in this experiment is real roughness, then it is found that ΔRa is smaller than 5 % when D is smaller than $D_{\max}/2$. When D is between $D_{\max}/2$ and $D_{\max}$, ΔRa is smaller than 20 %. Measured Ra and ΔRa for a specimen with Ra = 20 nm as plotted in Figure B.5 show that ΔRa is smaller than 3 % when D is about a half of $D_{\max}$.

B.4 Determination of criteria

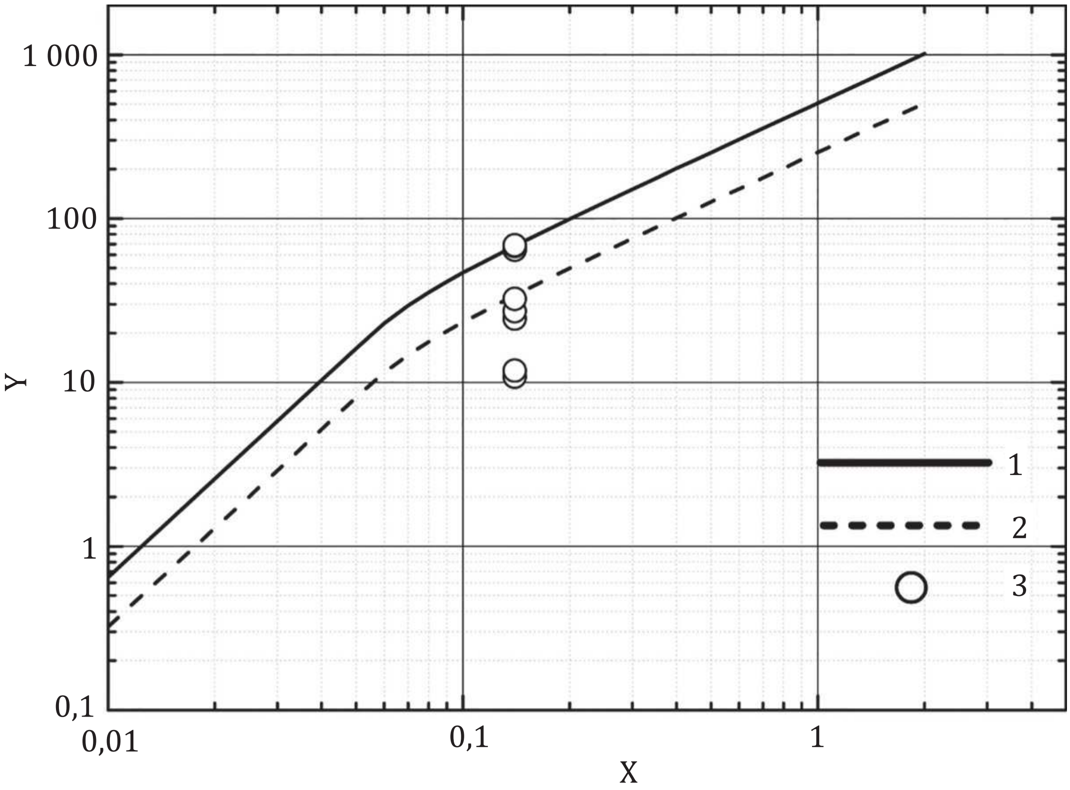
It is expected from the above description that ΔRa is smaller than 5 % when D is smaller than $D_{\mathrm{max}}/2$ (5 % criterion) and ΔRa is smaller than 20 % when D is between $D_{\mathrm{max}}/2$ and D_{max} (20 % criterion). Calculated D_{max} values for specimens with different RSm are shown in Figures 5 to 8.



Key

X horizontal axis of roughness profile

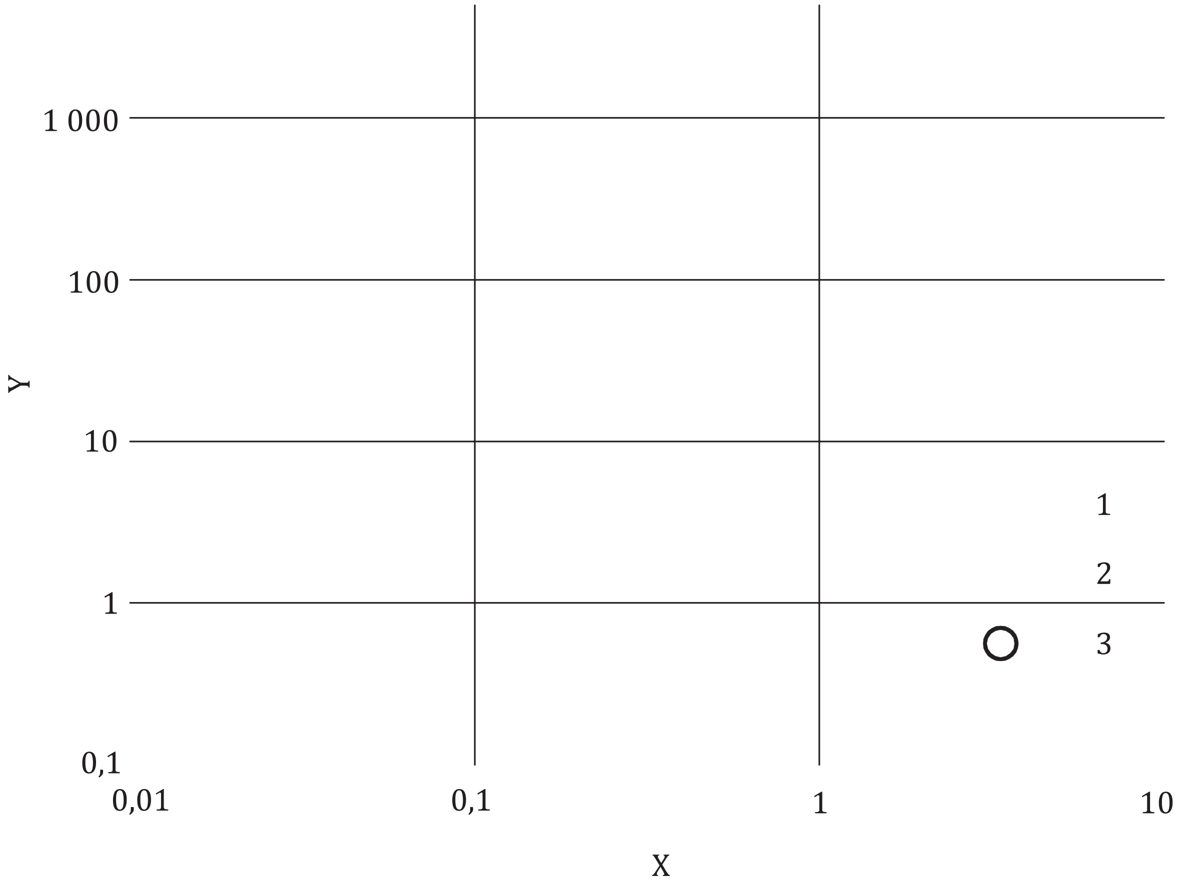
Figure B.1 — Model for probe-tip error evaluation



Key

1	solid line: 20 %-criterion	X	*RSm* in µm
2	dotted line: 5 %-criterion	Y	probe tip diameter in nm
3	measured points		

Figure B.2 — D_{max}, $D_{\mathrm{max}}/2$ and measured values for a specimen with *Ra* = 5 nm



Key

1 solid line: 20 %-criterion

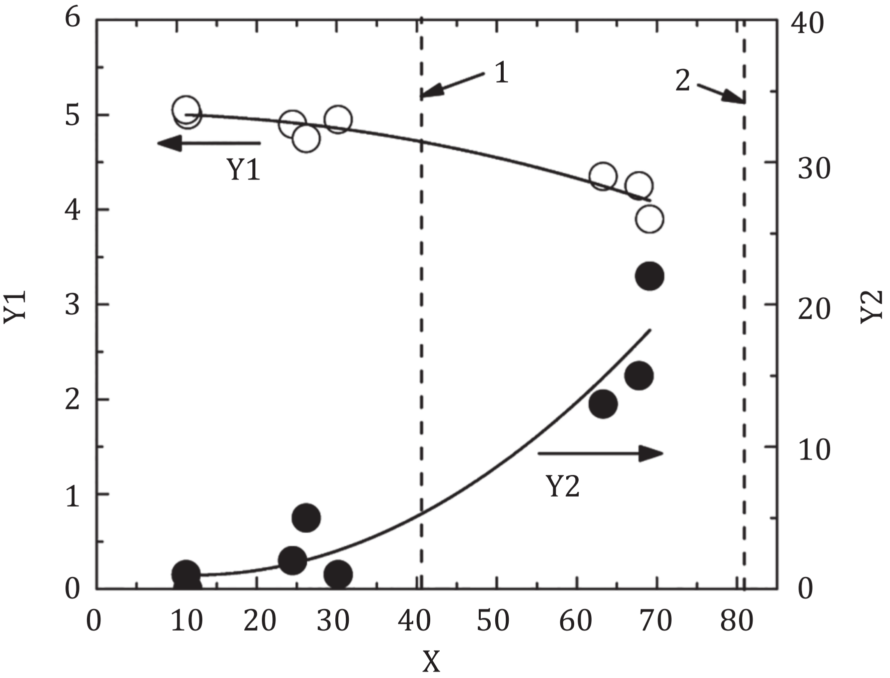
2 dotted line: 5 %-criterion

3 measured points

X *RSm* in µm

Y probe tip diameter in nm

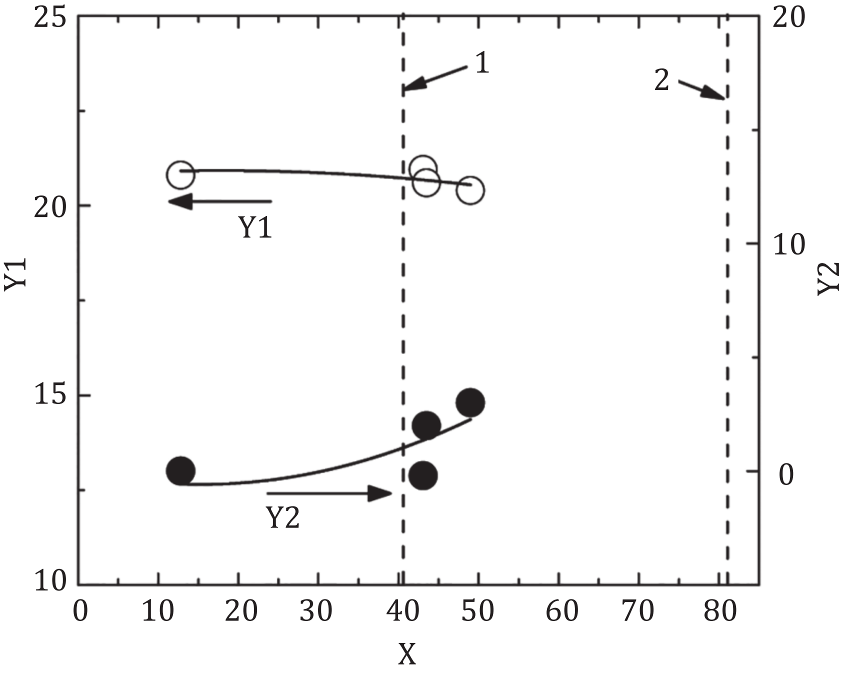
Figure B.3 — D_{max}, $D_{\mathrm{max}}/2$ and measured values for a specimen with Ra = 20 nm



Key

1	one half of D_{max}	X	probe tip diameter in nm
2	D_{max}	Y1	*Ra*
		Y2	ΔRa

Figure B.4 — Measured *Ra* and measurement error, Δ*Ra*, for specimen with *Ra* = 5 nm as a function of probe tip diameter, *D*



Key

1	one half of D_{max}	X	probe tip diameter in nm
2	D_{max}	Y1	*Ra*
		Y2	Δ*Ra*

Figure B.5 — Measured *Ra* and measurement error, Δ*Ra*, for specimen with *Ra* = 20 nm as a function of probe tip diameter, *D*

Bibliography

[1] ISO 11775, *Surface chemical analysis — Scanning-probe microscopy — Determination of cantilever normal spring constants*

[2] ISO 16610-21, *Geometrical product specifications (GPS) — Filtration — Part 21: Linear profile filters: Gaussian filters*

[3] ISO 25178-3, *Geometrical product specifications (GPS) — Surface texture: Areal — Part 3: Specification operators*

ICS 81.060.30

Price based on 24 pages