OLYMPUS

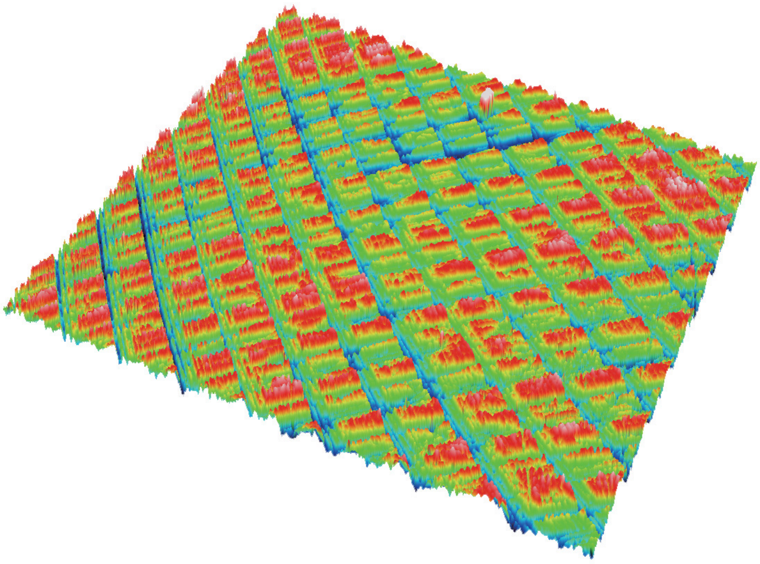
Measuring Laser Microscope

OLS5100

LEXT

Introduction to Surface Roughness Measurement

Roughness measurement guidebook



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Introduction to Noncontact Surface Roughness Measurement

Laser Confocal Scanning Microscopes and Roughness Measurement

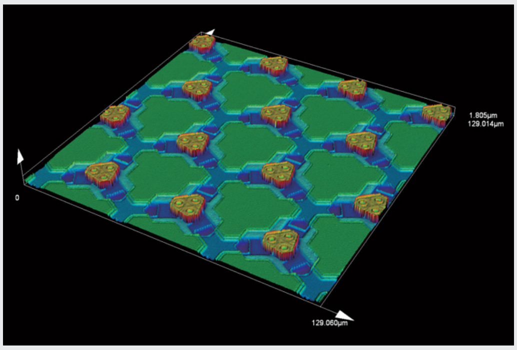
The spread of optical sensors

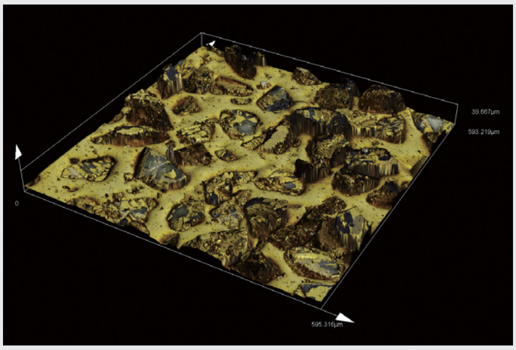
The transition to optical topographic measurement is important because of the proliferation of technological surfaces that cannot be measured at all or with sufficient fidelity using a conventional stylus. Many surfaces of interest, including those in fields like anthropology and archaeology, biotechnology, and engineering, require optical methods. Examples include high-pressure valve seats, battery electrodes, and even teeth. Microelectromechanical systems (MEMS) devices and other smaller parts also require optical technology.

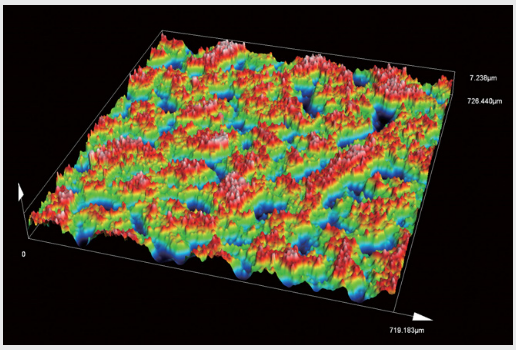
There are differing expectations and practices for each application, and optical sensors are now the common sense choice. Even small firms are adopting optical technology, either by using other companies' equipment or buying their own. Such firms are broadening the range of applications for optical technology, such as examining teeth and surfaces made by additive manufacturing.

Trends in surface metrology and analysis

Surface metrology provides value in discovering functional correlations between roughness and performance and between processing and roughness. These discoveries depend on good measurement fidelity and resolution as well as analyzing the right geometrical features at the appropriate scales. The method of data analysis is equally important along with the data acquisition capabilities of the measurement instrument. Since three-dimensional surface texture parameters are essential for defining irregular surface features, analysis based on 3D surface texture is important.







No longer dependent on Ra, Rz, and similar conventional indices of surface roughness, the science of modern surface measurement is developing innovative analytical methods acquired with high-quality measurement instruments.

The advantages of using an Olympus laser scanning microscope

Olympus' high-quality optics help eliminate many outliers before they occur. The quality of the resulting measurement is evident in multiscale analysis down to the finest scales.

The high-quality data produced by Olympus instruments minimize the problems caused by the amplification of errors in the calculation of finite approximations of derivatives for slopes and curvatures. Spike noise and other outliers that are often present in optical observations are generally eliminated by smoothing and similar filtering processes. However, such filtering processes are undesirable because they tend to eliminate correctly measured data along with the noise. Using an Olympus laser microscope, only the spike noise and other outliers are eliminated while the details of the observed data are preserved. The laser microscope's data processing capabilities are a significant advantage.

The broadness of range, fineness, and low-noise characteristics of Olympus laser microscopes deliver measurement results that are essential in the analysis of surface textures.

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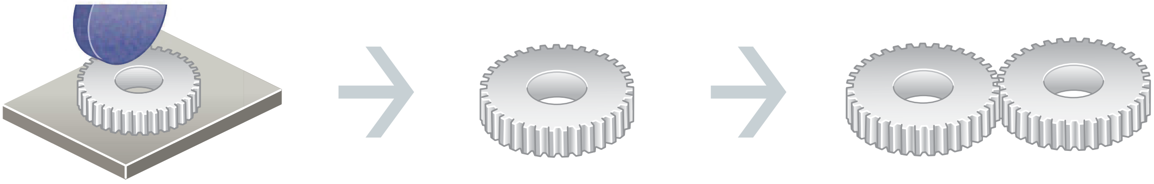
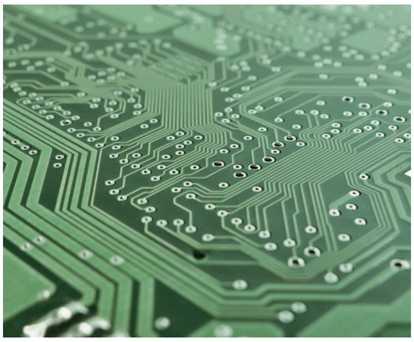
October, 2017

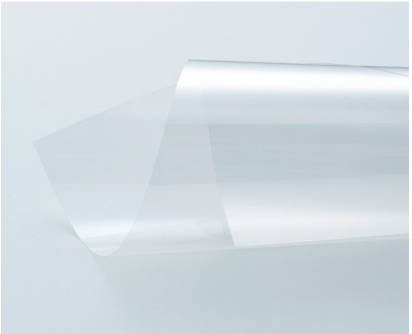
About Surface Roughness

What is surface roughness?

Surface roughness indicates the condition of processed surfaces.
Surface conditions are determined by visual appearance and tactile feel and are often described using expressions such as smooth-and-shiny, matte-and-textured, mat-silver, or mirror-finish. The differences in both appearance and texture are derived from the irregularities present on the surface of the object.
Irregularities cause roughness on a surface. Surface roughness is a numerical scale of the surface condition of the shininess (or texture) that is not dependent on visual or tactile sensation. Surface roughness plays a significant role in determining the characteristics of a surface.
Facial irregularities on components and materials are either created intentionally or produced by various factors including the vibration of cutting tools, the bite of the edge used, or the physical properties of the material. Irregularities have diverse sizes and shapes and overlap in numerous layers; the concavities/convexities affect the quality and functionality of the object surface. In consequence, the irregularity impacts the performance of the resulting product in terms of friction, durability, operating noise, and air tightness. In the case of assembly components, the surface feature affects the characteristics of the final product, including friction, durability, operating noise, energy consumption, and air tightness. The surface features also influence the product's quality, such as the ink/pigment application and varnish of printing paper and panel materials.







Olympus has been participating in the Technical Committee of the International Organization for Standardization (ISO/TC213) since 2011 to promote the standardization of 3D surface texture measurement. At the same time, we have work to 3D surface texture measurement techniques to industry.
Olympus is committed to offering 3D surface texture measurement solutions that comply with international standards, thereby contributing to the development of manufacturing.

Why surface roughness needs to be measured

The size and configuration of features have a significant influence on the quality and functionality of processed surfaces and the performance of the final products. Consequently, it is important to measure the roughness of surfaces to meet high performance standards for resulting end products.

Surface irregularities measured by classifying the height/depth and intervals of surface features to evaluate their concavity/convexity. The results are then analyzed in accordance with predetermined methods, subject to a calculation based on industrial quantification (*).

The favorable or adverse influence of surface roughness is determined by the size and shape of the irregularities and the use of the product.

The level of roughness must be managed based on the desired quality and performance of the surface.

The measurement and evaluation of surface roughness is an old concept with numerous established parameters indicating various criterion of roughness. The progress of processing technology and the introduction of advanced measurement instruments enables the evaluation of diverse aspects of surface roughness.

* The industrial quantity determines the quantitative properties defined by the method of measurement (cf: roughness; hardness) instead of physical quantities, such as mass and length.

Trends in surface roughness measurement

Measuring the surface features of components and industrial products and the qualitative management of the resulting data is increasing with the evolution of nanotechnology and the higher performance demands and size-reduction of electronic devices. Conventional stylus roughness gages and other instruments designed to acquire height information through mechanical contact with the surface being measured were broadly able to measure surface height/features and the superficial condition of the surfaces. However, the increase of soft samples, like films, and surface features that are smaller than the tip of the stylus probe led to the demand for non-contact measurement techniques, from linear measurement to nondestructive/precise area measurement. To meet these demands, laser microscopes were developed as instruments capable of providing accurate, `non-contact 3D measurement of the surface features of a sample within the presence of the atmosphere.

About Surface Roughness

Categories of surface texture parameters and applicable international standards

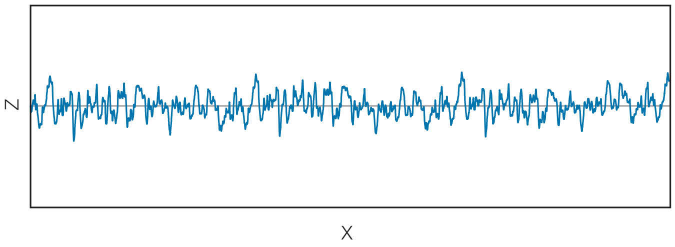
Superficial irregularities (roughness and undulation), dents, parallel grooves, and other characteristic surface features are collectively designated as “surface textures.” Converting these surface characteristics into numerical measurements is referred to as surface texture parameters.” Surface texture parameters are roughly categorized into the profile method and the areal method.

Profile method (line roughness measurement)

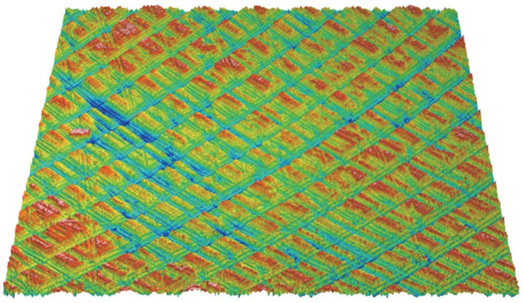
Conventionally, surface texture parameters were defined based on profile curves (curves indicated by the intersection of surfaces). The formal name for this method of measurement is the profile method, but it is also known as line roughness measurement. The surface profile is generally measured with stylus probe measurement instruments. ISO and other sets of international standards are designated for this method of measurement.

Areal method

Today, surface texture parameters are increasingly acquired through three-dimensional surface texture data with abundant areal information instead of the conventional two-dimensional contour profile curves used in profile method measurement. This is called the areal method. For the most part, the areal method involves non-contact measurement instruments based on optical observation.



Example of measurement using the profile method



Example of measurement using the areal method

Profile method versus the areal method

Measurement data acquired using the profile method is reliable since the data is obtained by directly tracing the surface with mechanical probes. Consequently, the profile method will likely remain a popular measurement technique for the foreseeable future. The disadvantages of the method are that it’s not suitable for soft material since the the contact probe can damage the surface being measured. In addition, since the measurement surface is evaluated based on the texture information obtained from a single section, the acquired data may not always reflect the irregularity characteristics of the overall surface area.

In contrast, most instruments based on non-contact three-dimensional measurement can work with soft materials without damaging the measurement surface. Also, three-dimensional data acquisition measures the surface characteristics over a large surface area, enabling users to characterize the orientation of parallel grooves and scratches that would be otherwise difficult to discern using the profile method. The areal method provides a lot of information and is effective at associating the required functionality of a surface, such as abrasion resistance, the adhesiveness between solids, and lubricant retention capability, with the surface parameters.

International standardization

The International Organization for Standardization (ISO) is promoting the designation of standards for areal measurement and many basic standards are have already been adopted. The following table lists primary standards applicable to the profile and the areal method.

The profile method standards were created assuming the exclusive use of contact probe-based measurement instruments. The standards designated unified measurement condition requirements including evaluation length, cut off, the radius of the probe tip, etc. In the case of the areal method, various measurement instruments based on different operating principles are used, making it impossible to introduce unified measurement condition requirements. Accordingly, users are required to determine the suitable measurement conditions that correspond to the purpose of the evaluation. Hints for determining the measurement conditions are described in the section “the essentials of surface roughness evaluation using laser microscopy.”

	Profile method type	Areal method type
Surface texture parameters	ISO 4287:1997	ISO 25178-2:2012
	ISO 13565:1996	
	ISO 12085:1996	
Measurement conditions	ISO 4288:1996	ISO 25178-3:2012
	ISO 3274:1996	
Filter	ISO 11562:1996	ISO 16610 series
Categorization of measurement instruments	-	ISO25178-6:2010
Calibration of measurement instruments	ISO 12179:2000	Under preparation
Standard test-pieces for calibration	ISO 5436-1:2000	ISO25178-70:2013
Graphic method	ISO 1302:2002	ISO25178-1:2016

Primary standards of the profile and areal methods

About Surface Roughness

Various measurement instruments are capable of measuring surface roughness

Surface roughness measurement instruments can be categorized into contact-based and non-contact-based instruments. There are pros and cons to both methods, and it is important to select the most suitable instrument based on your application.

Method	Measurement instrument	Merits	Demerits
Contact-based measurement	Stylus roughness instrument	● Enables reliable measurement as the sample surface is physically traced with styluses ● Maintains a long track record of use	● Limited to measuring a single section with a reduced quantity of acquired information ● In capable of conducting measurement of adhesive surfaces and soft samples ● Difficult to precisely position the probe ● Capable of measuring details smaller than the stylus probe tip diameter
Non-contact-based measurement	Coherence scanning interferometers	● Quick measurements ● Enables measurement of smooth surfaces of sub-nm order at low magnification	● Has trouble measuring rough surfaces ● Has trouble measuring samples with significant differences in brightness ● Low contrast makes it difficult to locate the areas subject to measurement ● Low XY resolution
	Laser Microscope	● High angle detection sensitivity, enabling analysis of steeply inclined slopes ● High XY resolution, providing for clear, high-contrast images	● Incapable of conducting sub-nanometer measurements ● Inferior height discrimination capabilities at lower magnification rates
	Digital microscope	● Enables many kinds of observations and a simple level of measurement	● Not suitable for measuring component roughness (suitable for measuring waviness) ● Incapable of measuring sub-nanometer irregularities ● Low XY resolution
	Scanning probe microscope (SPM)	● Enables measurement of sub-nanometer surfaces ● Enables measurement of samples with relatively high aspect ratio	● Difficulty in precisely positioning the probe ● Conducting the measurement takes time ● Not suitable for measuring μm irregularities

Description of technical glossaries

Profile method glossary

Primary profile curve

The curve obtained by applying a low-pass filter with a cutoff value of λs to the primary profile measured. The surface texture parameter calculated from the primary profile is referred to as the primary profile parameter (P-parameter).

Roughness profile

The profile derived from the primary profile by suppressing the long wave component using the high-pass filter with a cutoff value of λc. The surface texture parameter calculated from the roughness profile is referred to as the roughness profile parameter (R-parameter).

Waviness profile

The profile obtained by sequential application of profile filters with cutoff values of λf and λc to the primary profile. λf cuts off the long wave component while the short wave component is cut off with filter λc. The surface texture parameter calculated from the waviness profile is referred to as the waviness profile parameter (W-parameter).

Profile filter

The filter for the isolation of the long and short wave components contained in the profile. Three types of filters are defined:

λs filter: Filter designating the threshold between the roughness component and shorter wave components
λc filter: Filter designating the threshold between the roughness component and waviness components
λf filter: Filter designating the threshold between the waviness component and longer wave components

Cut-off wavelength

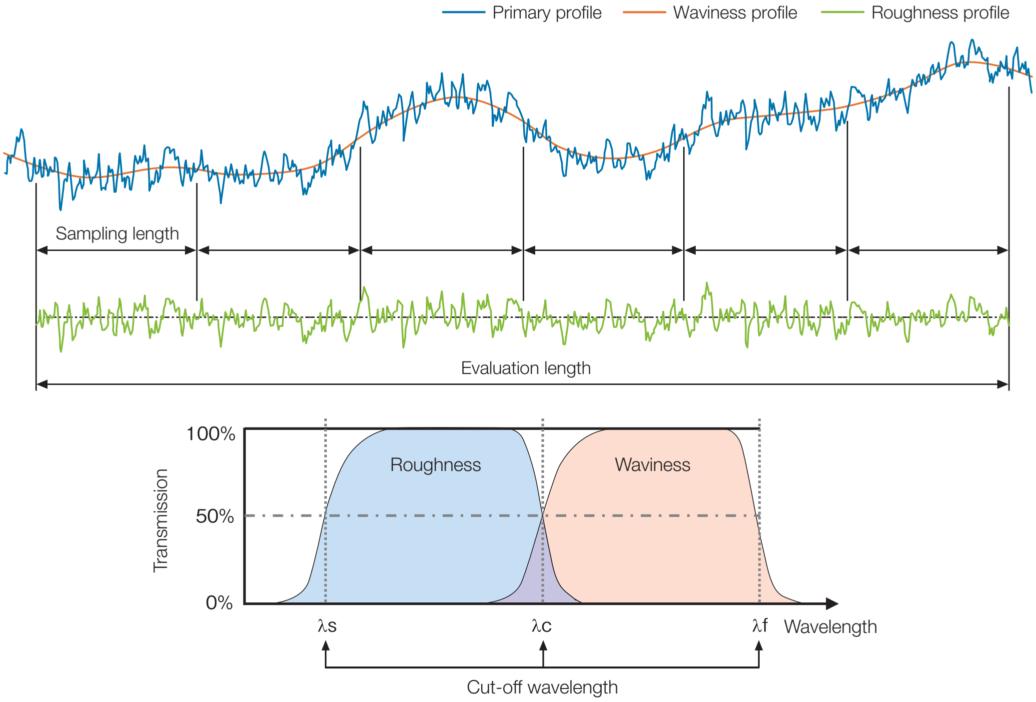
Threshold wavelength for profile filters. Wavelength indicating 50% transmission factor for a given amplitude.

Sampling length

The length in the direction of the X-axis used for the determination of profile characteristics.

Evaluation length

Length in the direction of the X-axis used for assessing the profile under evaluation.



Conceptual drawing of Profile method

About Surface Roughness

Description of technical glossaries

Areal method glossary

Scale limited surface

The surface data are serving as the basis for the calculation of areal surface texture parameters. S-F surface or S-L surface. Sometimes simply referred to as ‘surface.’

Areal filter

The filter for the separation of the long and short wave components contained in the scale-limited surfaces. Three types of filters are defined according to function:

S filter: Filter eliminates small wavelength components from scale-limited surfaces

L filter: Filter eliminates large wavelength components from scale-limited surfaces

F operation: Association or filter for the elimination of specific forms (spheres, cylinders, etc.)

NOTE) Gaussian filters are generally applied as S and L filters, and the total least square association is applied for the F operation.

Gaussian filter

A type of areal filter normally used in areal measurement. Filtration is applied by convolution based on weighting functions derived from a Gaussian function. The value of the nesting index is the wavelength of a sinusoidal profile for which 50% of the amplitude is transmitted.

Spline filter

A type of areal filter with smaller distortion in the peripheral edge when compared to the Gaussian filter.

Nesting index

The index representing the threshold wavelength for areal filters. The nesting index for the application of areal Gaussian filters are designated in terms of units of length and equivalent to the cutoff value in the profile method.

S-F surface

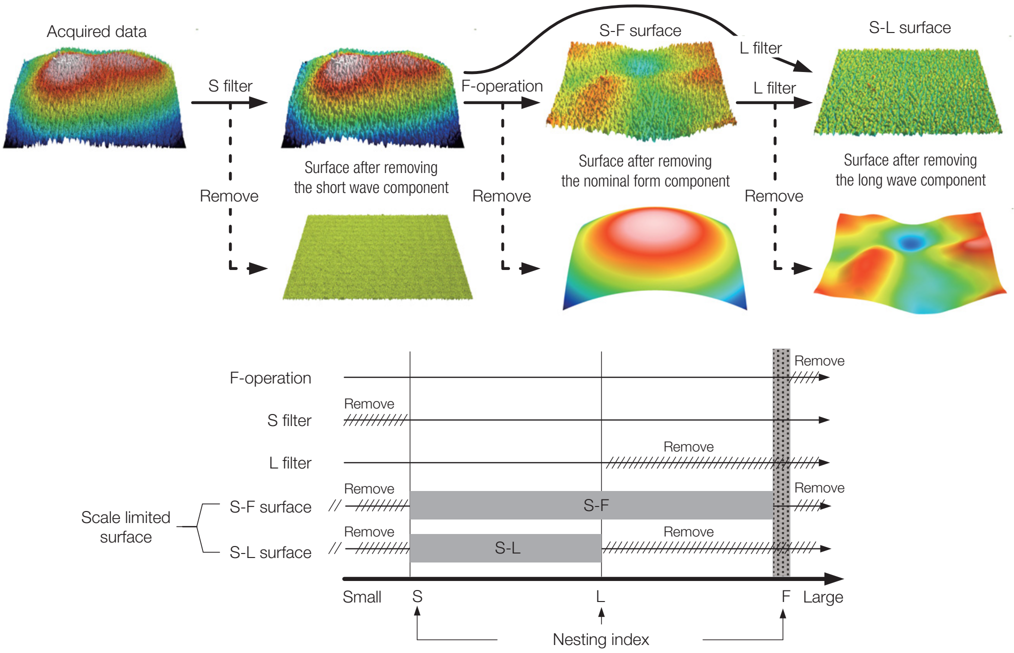
The surface obtained by eliminating small wavelength components using the S filter and then processed by removing certain form components using the F operation.

S-L surface

The surface obtained by eliminating small wavelength components using the S filter and then eliminating large wavelength components using L filtration.

Evaluation area

A rectangular portion of the surface designated for characteristic evaluation. The evaluation area shall be a square (if not otherwise specified).



Conceptual drawing of the areal method

Essentials of surface roughness evaluation using laser microscopy

Point 1 Guide to selecting objective lenses

1) From the items listed below, select the appropriate objective lenses (◎, ○) based on the item to be measured (roughness, waviness, or unevenness). Be sure that the working distance (W.D.) value exceeds the clearance between the sample and the lens.

2) If there are multiple objective lenses candidates, make a final selection. The size of the field of the measurement is typically chosen to be five times the scale of the coarsest structure of interest.

— In case multiple candidates are available, select the objective lens with the largest possible numerical aperture (N.A.).

— If no suitable lens is available, either return to candidate selection and include objective lenses marked as △ or consider expanding the area of measurement using the stitching function.

Objectives	Specification				Measurement item		
	Numerical Aperture (N.A.)	Working Distance (W.D.) (Units: mm)	Focusing spot diameter* (Units: µm)	Field of measurement** (Units: µm)	Roughness	Waviness	Unevenness (Z)
MPLFLN2.5x	0.08	10.7	6.2	5120×5120	×	×	×
MPLFLN5x	0.15	20	3.3	2560×2560	×	×	×
MPLFLN10xLEXT	0.3	10.4	1.6	1280×1280	×	○	△
MPLAPON20xLEXT	0.6	1	0.82	640×640	△	○	○
MPLAPON50xLEXT	0.95	0.35	0.52	256×256	◎	○	◎
MPLAPON100xLEXT	0.95	0.35	0.52	128×128	◎	○	◎
LMPLFLN20xLEXT	0.45	6.5	1.1	640×640	△	○	○
LMPLFLN50xLEXT	0.6	5	0.82	256×256	△	○	○
LMPLFLN100xLEXT	0.8	3.4	0.62	128×128	○	○	◎
SLMPLN20x	0.25	25	2	640×640	×	○	△
SLMPLN50x	0.35	18	1.4	256×256	×	○	△
SLMPLN100x	0.6	7.6	0.82	128×128	△	○	○
LCPLFLN20xLCD	0.45	7.4-8.3	1.1	640×640	△	○	○
LCPLFLN50xLCD	0.7	3.0-2.2	0.71	256×256	○	○	○
LCPLFLN100xLCD	0.85	1.0-0.9	0.58	128×128	○	○	◎

∗: Theoretical value.

∗∗: Standard value when using OLS5100.

◎: Most suitable.
○: Suitable.
△: Acceptable depending on usage.
×: Not suitable.

Essentials of surface roughness evaluation using laser microscopy

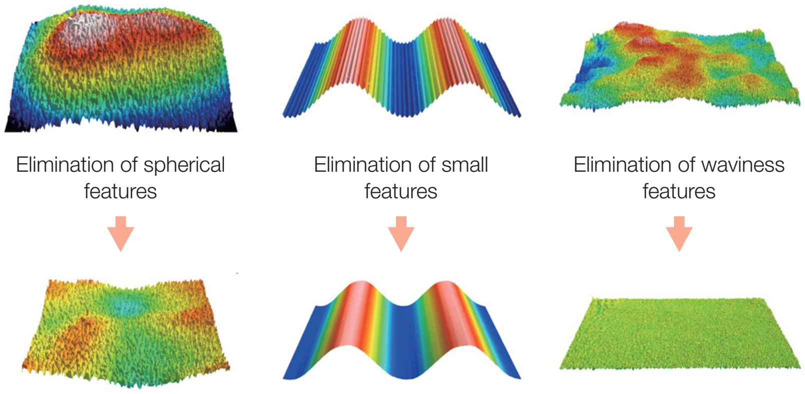
Point 2 Method of filter application

The functionality of the respective filters, the combination of filters, and the size of the filters used in surface feature analysis are as described below:
The filtering conditions are determined in accordance with the objectives of the analysis.

Filter functionality

In conducting surface feature parametric analysis, the application of three types of filters (F operation, S filter, and L filter) should be considered for the surface texture data acquired in accordance with the objectives of the measurement.

Nominal form components of samples (spheres, cylinders, curves, etc.) are eliminated.	Measurement noise and small feature components are eliminated.	Waviness components are eliminated.



Elimination of spherical features

Elimination of small features

Elimination of waviness features

Combination of filters

A total of eight combinations are available for the three filters (F operation, S filter, and L filter). Select the combination of filters to be applied referencing the list of measurement objectives indicated in the following table.

－: Non-application ○: Application

Intended purpose	When analyzing raw acquired data	When eliminating waviness component	When eliminating spheres, curves and other form components	When eliminating spheres, curves and other form components in addition to the waviness component	When eliminating small roughness components and noises	When eliminating small roughness components, noises and waviness components	When eliminating spheres, curves and other form components along with small roughness components and noises	When eliminating small roughness components and noises, spheres, curves and other feature components in addition to the waviness component
F-operation	-	-	○	○	-	-	○	○
S filter	-	-	-	-	○	○	○	○
L filter	-	○	-	○	-	○	-	○

Filter size (nesting indices)

●Filtering strength (separating capabilities) is referred to as nesting indices (L filters are alternately called cutoffs.)

  —The S filter eliminates increasingly more detailed feature components the larger the nesting index value is.

  —The L filter eliminates increasingly more waviness feature components the smaller the nesting index value is.

●Although the use of numerical values (0.5, 0.8, 1, 2, 2.5, 5, 8, 10, 20) are recommended when defining nesting index values, the following restrictions apply:

  —The nesting index value for S filters needs to be specified to exceed the optical resolution (≒ focusing spot diameter) and at least three times the value of the data sampling interval.

  —The nesting index for the L filter needs to be set to a value smaller than the area of measurement (length of the narrow side of the rectangular area).

Point 3 Selecting the roughness parameter

Depending on the purpose of the evaluation, the analysis conducted based on the following parameters are considered to be effective:

Example of purpose	Parameter, or method of analysis	Page
(1) Evaluating the unevenness	Sq, Sa, Sz, Sp, Sv	P.13
(2) Evaluating the height distribution	Ssk, Sku, Histogram analysis	P.14
(3) Evaluating the fineness	Sal, Sdq, Sdr	P.15
(4) Evaluating the direction	Std, Str, directional plotting	P.16
(5) Evaluating the periodicity	PSD	P.17
(6) Evaluating the dominant feature component	PSD	P.18
(7) Evaluating the quantity and tip configuration of protrusions	Spd, Spc	P.19
(8) Evaluating the variation before/after abrasion	Sk, Spk, Svk	P.20

Detailed explanations of items (1) to (8) are provided in the next section using specific examples.

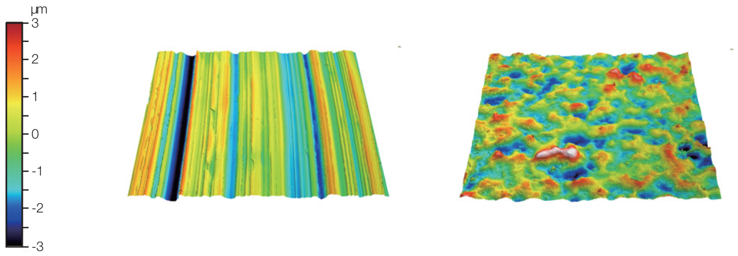
Selecting the roughness parameter

Evaluating the unevenness (Sq, Sa, Sz, Sp, Sv)

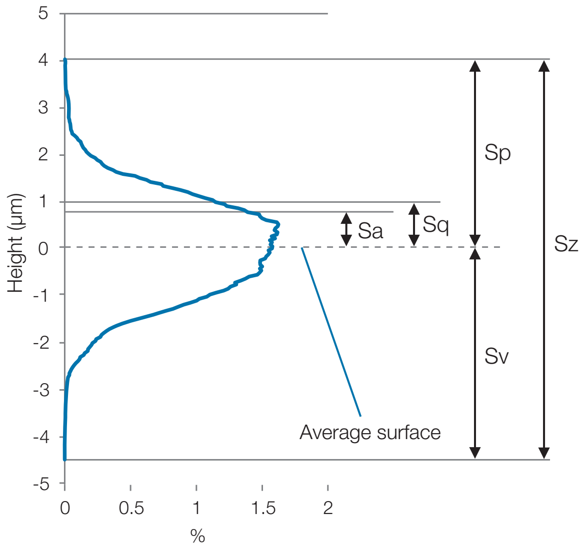
The unevenness can be evaluated using the height parameter (Sq, Sa, Sz, Sp, and Sv). Within the histogram, height parameters have a relationship as indicated below.

Sq (squared mean height) is equivalent to the standard deviation of height distribution and is an easy-to-handle statistical parameter. Sa (arithmetic mean height) is the mean difference in height from the mean plane. When the height distribution is normal, the relationship between the parameters Sq and Sa becomes Sa≒0.8*Sq. As parameters Sz, Sq, and Sv utilize maximum and minimum height values, the stability of the results may be adversely affected by measurement noise.

Height parameter is a parameter determined solely by the distribution of height information. Accordingly, the characteristics of horizontal features are not reflected in these parameters.



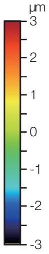
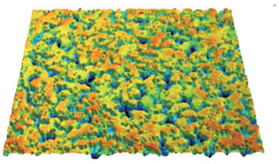
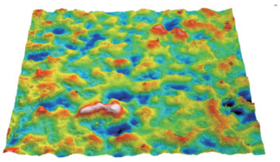
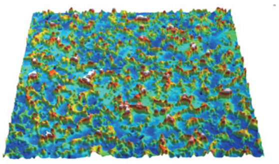
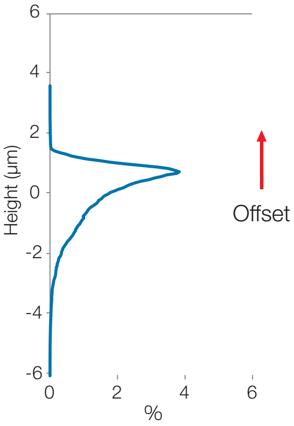
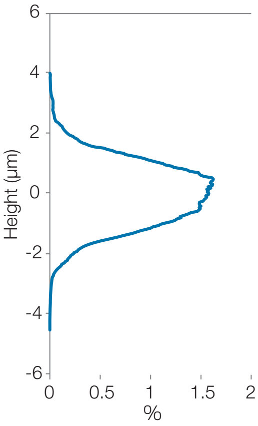
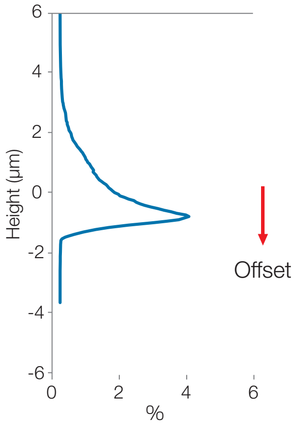
Sq	1µm	1µm
Sa	0.8µm	0.81µm
Sz	5.53µm	8.57µm
Sp	1.98µm	4.04µm
Sv	3.55µm	4.53µm



Evaluating the height distribution (Ssk, Sku, histogram)

The height distribution is generally evaluated in the form of histogram charts. Ssk is a parameter used in the evaluation of the degree of asymmetry in the graphic representation (distribution) of the histogram chart.

Ssk = 0 signifies that the difference in height is distributed uniformly, while minus values of the parameter indicate a deviation to the higher side and plus indicates a deviation to the lower side. In samples with the higher features whittled away due to sliding abrasion, Ssk values tend to indicate negative values. Because of this, the parameter is sometimes used as an evaluation index for the extent of sliding abrasion.

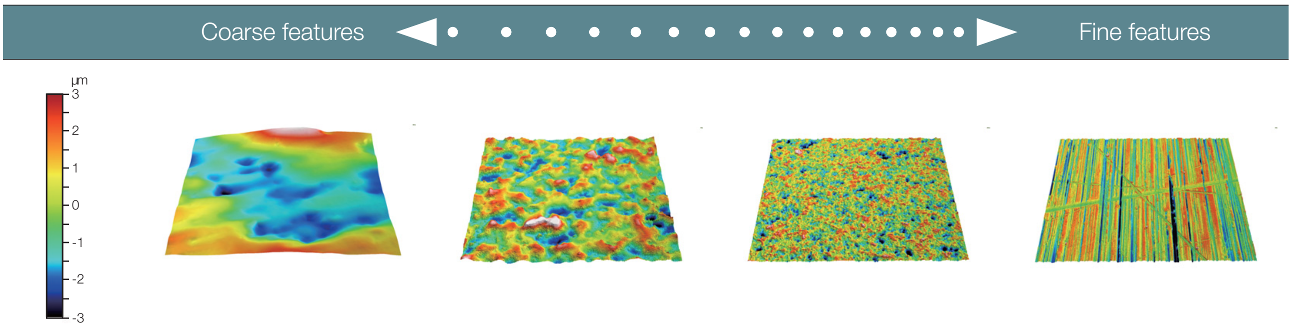
	Distribution offset to the higher side	Uniform distribution	Distribution offset to the lower side
			
Histogram			
Ssk	-1.33	0.00	1.33

Selecting the roughness parameter

Evaluating the fineness
(Sal, Sdq, Sdr)

The Sal parameter provides a numerical index of the density of similar structures in units of length. Features become finer as the value gets smaller.

Indirect indices representing the fineness of features include local gradients and the superficial area. Sdq is the mean value of local gradients present on the surface, while Sdr is a parameter indicating the rate of growth in the superficial area. If height parameters such as Sa and Sq are on a comparable level, the degree of fineness becomes finer as parameters Sdq (gradient) and Sdr (superficial area) become larger.

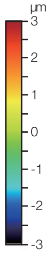
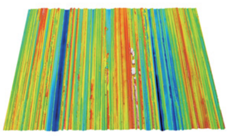
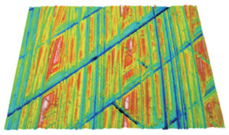
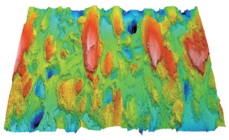
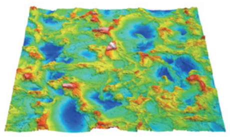
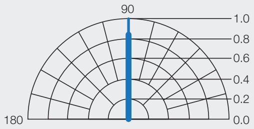
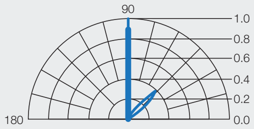
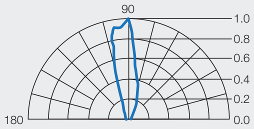
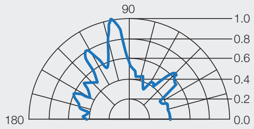


Sq	1.0µm		1.0µm		1.0µm		1.0µm
Sa	0.8µm		0.81µm		0.77µm		0.78µm
Sal	187µm	>	42.5µm	>	21.6µm	>	10.3µm
Sdq	0.062	<	0.18	<	0.38	<	0.4
Sdr	0.19%	<	1.50%	<	6.20%	<	6.80%

Evaluating the orientation
(Std, Str, directional plotting)

The orientation plot represents the directional properties of surface features as an angular chart. Plotted peaks become sharper as the orientation becomes pronounced. The strength of orientation is normalized, so the strongest peak is in contact with the outermost circle. Within an orientation plot, the Std parameter indicates the angle of peaks sequentially from the largest peak.

The Str parameter is a numerical representation of the strength of orientation. Str<0.3 signifies a (directional) anisotropic surface, while Str>0.5 represents an isotropic surface.

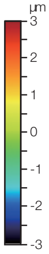
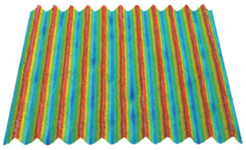
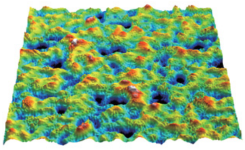
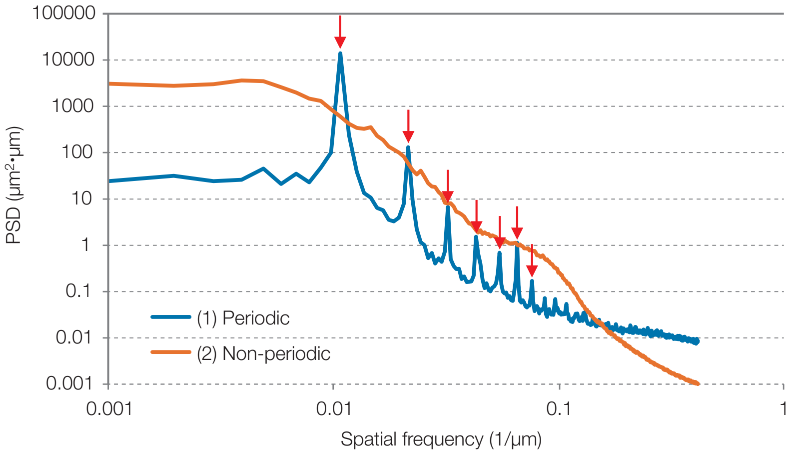
	Strong orientation toward a single direction	Strong orientation toward multiple directions	Weak orientation	No orientation
				
Orientation Plot				
Std	First: 90degrees Second: -- degrees Third: -- degrees	First: 90degrees Second: 45degrees Third: -- degrees	First: 90degrees Second: -- degrees Third: -- degrees	First: 100degrees Second: 125degrees Third: 45degrees
Str	0.07	0.07	0.26	0.77

Selecting the roughness parameter

Evaluating the periodicity (PSD)

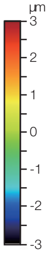
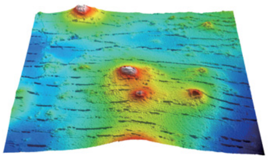
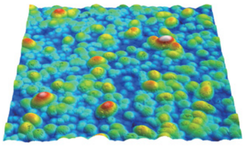
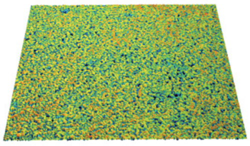
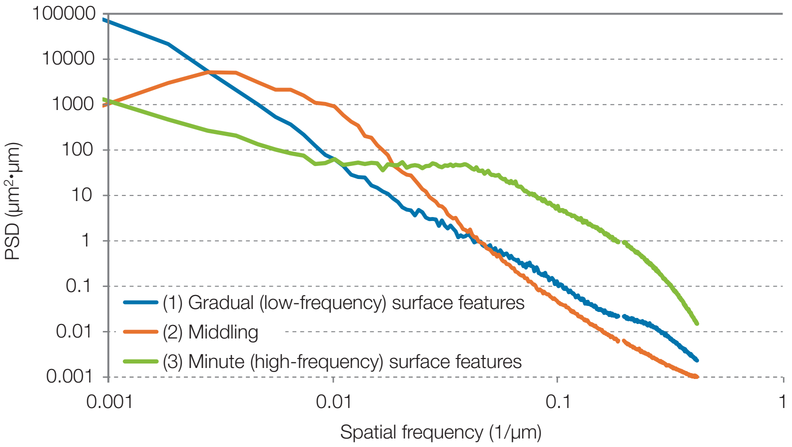
Power spectral density (PSD) represents the magnitude of surface unevenness for the respective spatial frequency. In samples with periodicity, peaks (arrows) are present in the PSD chart. The frequency of the periodicity (inverse number of the cycle) can be obtained by determining the horizontal axis of the peak.

The chart shows a general decline to the right if no periodicity is present.

<table>
<tr><th></th><th>(1) Periodic</th><th>(2) Non-periodic</th></tr>
<tr><td> </td><td></td><td></td></tr>
<tr><td>Sq</td><td>1.0μm</td><td>1.0μm</td></tr>
<tr><td>PSD</td><td colspan="2"> </td></tr>
</table>

Evaluating the dominant feature component (PSD)

Power spectral density (PSD) represents the magnitude of surface unevenness for respective spatial frequency “Gradual,” “minute,” and similar feature characteristics are reflected in the PSD charts.
In gradual surface features, the values on the low-frequency end (left side of the chart) tend to be larger. In minute surface features, the values on the high-frequency end (right side of the chart) tend to be larger.

	(1) Gradual (low-frequency) surface features	(2) Intermediate	(3) Minute (high-frequency) surface features
			
Sq	1.0µm	1.0µm	1.0µm
PSD			

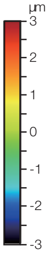
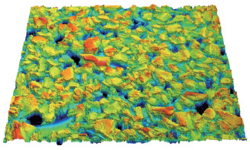
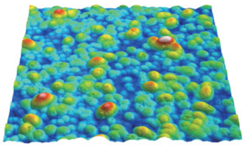
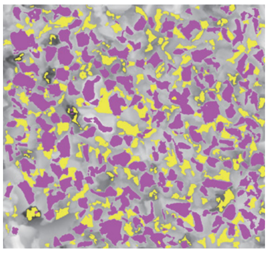
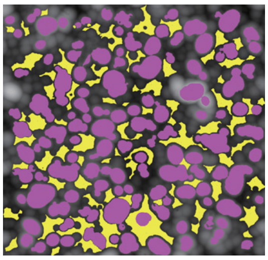
Evaluating the quantity and tip configuration of peaks (Spd, Spc)

Peaks present on the surface relate to the osculation of objects, friction, abrasion, and similar phenomena.

The feature image indicates the categorized topographical characteristics (peaks, valleys, ridge lines, and channel lines) of the surfaces. The Spd parameter represents the density (number of features per unit area) of surface features categorized into peaks (colored pink) within the feature image.

The Spc parameter represents the mean curvature radius of peaks for surface features categorized into peaks within the feature image.

As the Spc value becomes larger, the curvature of peaks grow smaller (sharper), and the curvature increases (obtuse) as the value gets smaller.

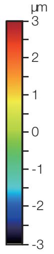
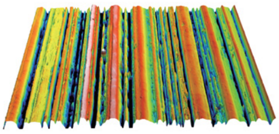
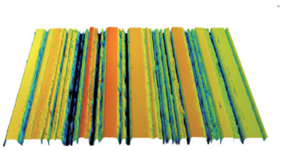
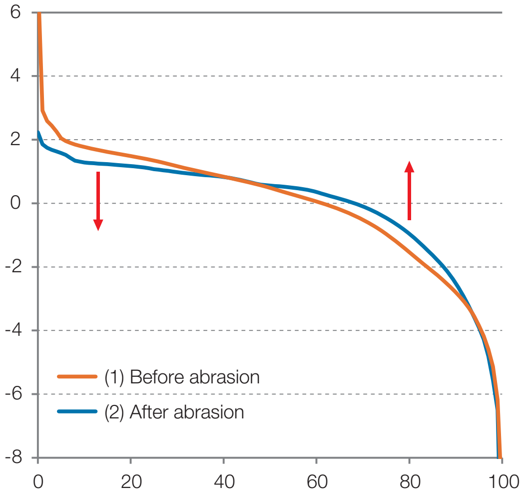
	Surface with sharp peaks	Surface with gradual peaks
		
Sq	1.0µm	1.0µm
Feature image		
	🟪Peaks 🟨Valleys	
Spd	847 mm^{-2}	138 mm^{-2}
Spc	618 mm^{-1}	69 mm^{-1}

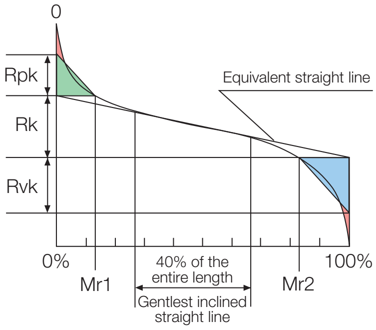
Evaluating the variation before/after abrasion (Sk, Spk, Svk)

Generally, abrasion progresses from the surface’s highest position. The use of height distribution based parameters is effective in the evaluation of abrasion status.

With the progress of abrasion, the curve in the higher portion of the material ratio curve moves downward, while the curve on the lower portion shifts upward.

The values for the parameters Sk and Spk decline in correspondence with the progress of abrasion.

	(1) Before abrasion	(2) After abrasion
		
Sq	1.9µm	1.7µm
Sk	3.2µm	1.7µm
Spk	1µm	0.46µm
Material ratio curve		



Profile method (linear roughness)

Amplitude parameters (peak and valley) (ISO4287:1997)	Symbol	Equivalent areal parameters	Page
Maximum height	Pz, Rz, Wz	Sz	P.22
Maximum profile peak height	Pp, Rp, Wp	Sp	P.22
Maximum profile valley depth	Pv, Rv, Wv	Sv	P.22
Mean height	Pc, Rc, Wc	-	P.23
Total height	Pt, Rt, Wt	-	P.23
Amplitude average parameters (ISO4287:1997)			
Arithmetic mean deviation	Pa, Ra, Wa	Sa	P.24
Root mean square deviation	Pq, Rq, Wq	Sq	P.24
Skewness	Psk, Rsk, Wsk	Ssk	P.24
Kurtosis	Pku, Rku, Wku	Sku	P.25
Spacing parameters (ISO4287:1997)			
Mean width	PSm, RSm, WSm	-	P.25
Hybrid parameters (ISO4287:1997)			
Root mean square slope	Pdq, Rdq, Wdq	Sdq	P.25
Material ratio curves and related parameters (ISO4287:1997)			
Material ratio	Pmr (c), Rmr (c), Wmr (c)	Smr (c)	P.26
Profile Section height difference	Pdc, Rdc, Wdc	Sxp NOTE1)	P.26
Relative material ratio	Pmr, Rmr, Wmr	-	P.26
Parameters of surface having stratified functional properties (ISO13565-2:1996)			
Core roughness depth	Rk	Sk	P.27
Reduced peak height	Rpk	Spk	P.27
Reduced valley height	Rvk	Svk	P.27
Material portion	Mr1	Smr1	P.27
Material portion	Mr2	Smr2	P.27
Motif parameters (ISO12085:1996)			
Mean spacing of roughness motifs	AR	-	P.27
Mean depth of roughness motifs	R	-	P.27
Maximum depth of roughness motifs	Rx	-	P.27
Mean spacing of waviness motifs	AW	-	P.27
Mean depth of waviness motifs	W	-	P.27
Maximum depth of waviness motifs	Wx	-	P.27

NOTE 1) Condition of calculation may differ between profile and three-dimensional methods.

Amplitude parameters (peak and valley)

Maximum height (Rz)

Represents the sum of the maximum peak height Zp and the maximum valley depth Zv of a profile within the reference length.

*Indicated as Ry within JIS' 94

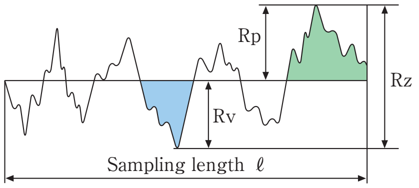
*Profile peak: Portion above (from the object) the mean profile line (X-axis)

*Profile valley: Portion below (from the surrounding space) the mean profile line (X-axis)

- **Pz** Maximum height of the primary profile
- **Wz** Maximum height of the waviness

POINT Although frequently used, max height is significantly influenced by scratches, contamination, and measurement noise due to its reliance on peak values.

$$Rz = Rp + Rv$$



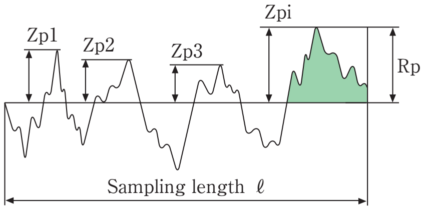
(In the case of roughness profile)

Maximum profile peak height (Rp)

Represents the maximum peak height Zp of a profile within the sampling length.

- **Pp** The maximum peak height of the primary profile
- **Wp** The maximum peak height of the waviness profile

$$Rp = \max (Z(x))$$



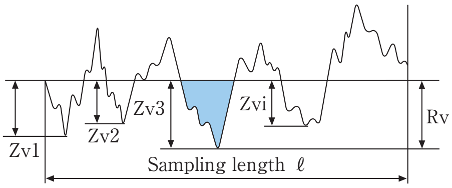
(In the case of roughness profile)

Maximum profile valley depth (Rv)

Represents the maximum valley depth Zv of a profile within the sampling length.

- **Pv** The maximum valley depth of the primary profile
- **Wv** The maximum valley depth of the waviness profile

$$Rv = \min (Z(x))$$



(In the case of roughness profile)

Profile method (linear roughness) parameters

Amplitude parameters (peak and valley)

Mean height (Rc)

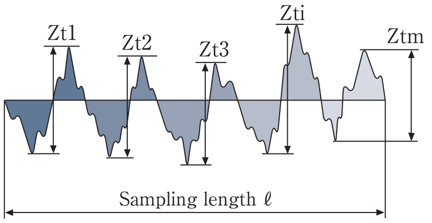
Represents the mean for the height Zt of profile elements within the sampling length.

＊Profile element: A set of adjacent peaks and valleys
＊Minimum height and minimum length to be discriminated from the peaks (valleys).

Minimum height discrimination: 10% of the Rz value
Minimum length discrimination: 1% of the reference length

- **Pc** The mean height of the primary profile element
- **Wc** The mean height of the waviness element

$$Rc = \frac{1}{m}\sum_{i=1}^{m} Zti$$



(In the case of roughness profile)

Total height (Rt)

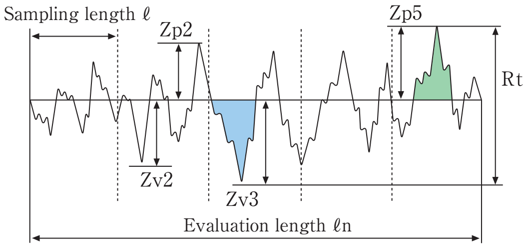
Represents the sum of the maximum peak height Zp and the maximum valley depth Zv of a profile within the evaluation length, not sampling length.

＊Relationship Rt≧Rz applies for all profiles.

- **Pt** The maximum total height of the profile (Rmax in the case of JIS’82)
- **Wt** The maximum total height of the waviness

POINT Rt is a stricter standard than Rz in that the measurement is conducted against the evaluation length.
It should be noted that the parameter is significantly influenced by scratches, contamination, and measurement noise due to its utilization of peak values.

$$Rt = \max(Zpi) + \max(Zvi)$$



(In the case of roughness profile)

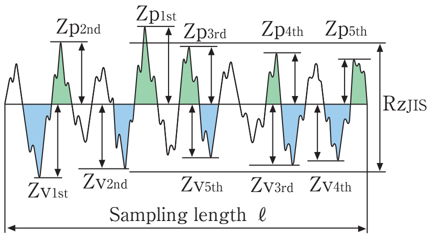
Ten-point mean roughness (Rzjis)

Represents the sum of the mean value for the height of the five highest peaks and the mean of the depth of the five deepest valleys of a profile within the sampling length.

＊Indicated as Rz within JIS’94

POINT Rzjis is equivalent to the parameter Rz of the obsolete JIS standard B0601:1994. Although ten-point mean roughness was deleted from current ISO standards, it was popularly used in Japan and was retained within the JIS standard as parameter Rzjis.

$$Rzjis = \frac{1}{5}\sum_{j=1}^{5}(Zpj + Zvj)$$



(In the case of roughness profile)

Amplitude average parameters

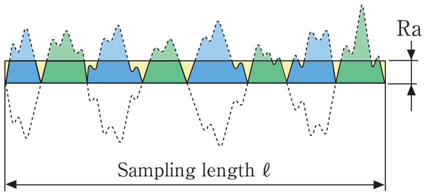
Arithmetic mean deviation (Ra)

Represents the arithmetric mean of the absolute ordinate Z(x) within the sampling length.

- **Pa** The arithmetic mean height of the primary profile
- **Wa** The arithmetic mean waviness

POINT One of the most widely used parameters is the mean of the average height difference for the average surface. It provides for stable results as the parameter is not significantly influenced by scratches, contamination, and measurement noise.

$$\mathbf{Ra} = \frac{1}{\ell}\int_0^{\ell}|Z(x)|dx$$



(In the case of roughness profile)

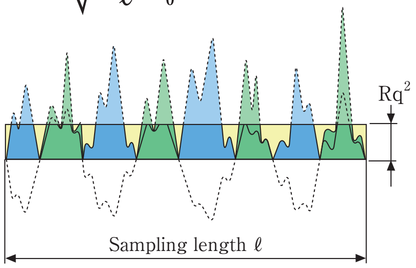
Root mean square deviation (Rq)

Represents the root mean square for Z(x) within the sampling length.

- **Pq** The root mean square height for the primary profile
- **Wq** Root mean square waviness

POINT This is one of the most widely used parameters and is also referred to as the RMS value. The parameter Rq corresponds to the standard deviation of the height distribution. The parameter provides for easy statistical handling and enables stable results as the parameter is not significantly influenced by scratches, contamination, and measurement noise.

$$\mathbf{Rq} = \sqrt{\frac{1}{\ell}\int_0^{\ell} Z^2(x)\,dx}$$



(In the case of roughness profile)

Skewness (Rsk)

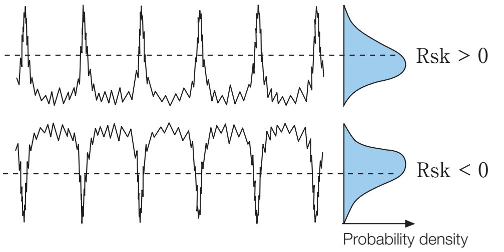
The quotient of the mean cube value of Z(x) and the cube of R8 within a sampling length.

Rsk=0: Symmetric against the mean line (normal distribution)
Rsk>0: Deviation beneath the mean line
Rsk<0: Deviation above the mean line

- **Psk** The skewness of the primary profile
- **Wsk** The skewness of the waviness profile

POINT This parameter concerns height distribution. It is suitable for evaluating the abrasion and oil sump of lubricants for slide planes.

$$\mathbf{Rsk} = \frac{1}{Rq^3}\left[\frac{1}{\ell}\int_0^{\ell} Z^3(x)\,dx\right]$$



(In the case of roughness profile)

Profile method (linear roughness) parameters

Amplitude average parameters

Kurtosis (Rku)

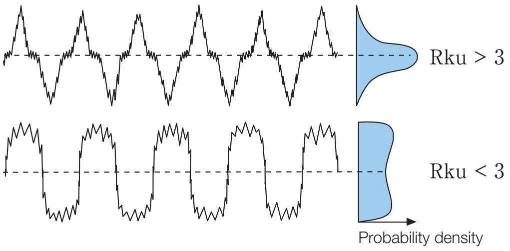
The quotient of the mean quadratic value of Z(x) and the fourth power of Rq within a sampling length.

Rku=3: Normal distribution
Rku>3: The height distribution is sharp
Rku<3: The height distribution is even

- ● **Pku** The Kurtosis of the primary profile
- ● **Wku** The Kurtosis of the waviness profile

POINT This parameter relates to the tip geometry of peaks and valleys and is suitable for analyzing the degree of contact between two objects.

$$\mathbf{Rku} = \frac{1}{\mathbf{Rq}^4}\left[\frac{1}{\ell}\int_0^{\ell} \mathbf{Z}^4(\mathbf{x})\,\mathbf{dx}\right]$$



(In the case of roughness profile)

Spacing parameters

Mean width (RSm)

Represents the mean for the length Xs of profile elements within the sampling length.

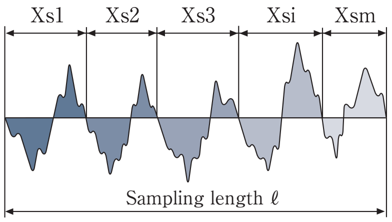
＊Indicated as Sm within JIS’94
＊Minimum height and minimum length to be discriminated from peaks (valleys).

Minimum height discrimination: 10% of the Rz value
Minimum length discrimination: 1% of the reference length

- ● **PSm** Mean width of the primary profile element
- ● **Wc** Mean width of the waviness element

POINT This parameter is used to evaluate the horizontal size of parallel grooves and grains instead of the height parameters.

$$\mathbf{RSm} = \frac{1}{\mathbf{m}}\sum_{i=1}^{m} \mathbf{Xsi}$$



(In the case of roughness profile)

Hybrid parameters

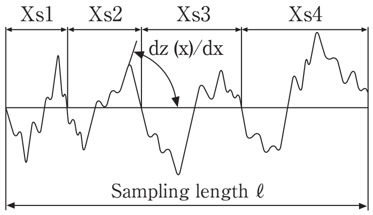
Root mean square slope (Rdq)

Represents the root mean square for the local slope dz/dx within the sampling length.

- ● **Pdq** The root mean square slope for the primary profile
- ● **Wdq** The root mean square slope for the waviness

POINT The steepness of the surface can be numerically represented with this parameter.

$$\mathbf{Rdq} = \sqrt{\frac{1}{\ell}\int_0^{\ell}\left(\frac{\mathbf{d}}{\mathbf{dx}}\mathbf{Z(x)}\right)^2 \mathbf{dx}}$$



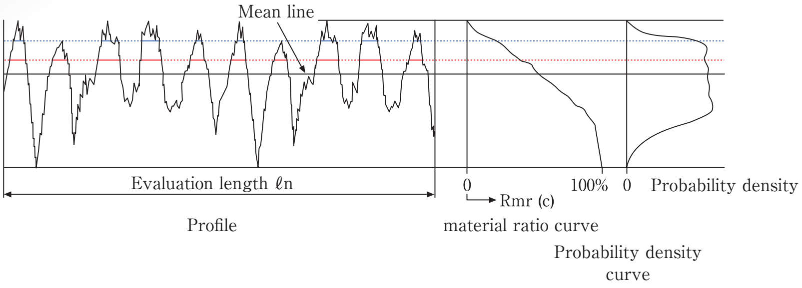
(In the case of roughness profile)

Material ratio curves and related parameters

Material ratio curve and probability density curves

Material ratio curves signify the ratio of materiality derived as a mathematical function of parameter c, where c represents the height of severance for a specific sample. This is also referred to as the bearing curve (BAC) or Abbott curve.

Probability density curves signify the probability of occurrence for height Zx. The parameter is equivalent to the height distribution histogram.



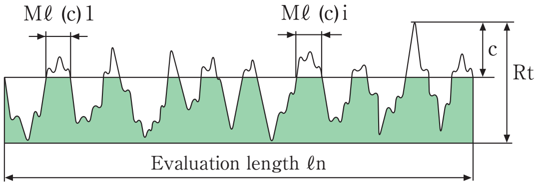
(In the case of roughness profile)

Material ratio (Rmr(c))

Indicates the ratio of the material length Ml(c) of the profile element to the evaluation length for the section height level c (% or μm).

- **Pmr(c)** The material length rate of the primary profile (formerly tp)
- **Wmr(c)** The material length rate of the waviness

$$\mathrm{Rmr}\,(c) = \frac{1}{\ell n}\sum_{i=1}^{m} M\ell\,(c)\,i$$



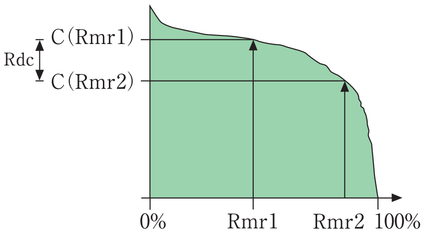
(In the case of roughness profile)

Profile section height difference (Rdc)

Rdc signifies the height difference in section height level c, matching the two material ratios.

- **Pdc** The section height level difference for the primary profile
- **Wdc** The section height level difference for the waviness profile

$$\mathrm{Rdc} = c\,(\mathrm{Rmr1}) - c\,(\mathrm{Rmr2}) : \mathrm{Rmr1} < \mathrm{Rmr2}$$



(In the case of roughness profile)

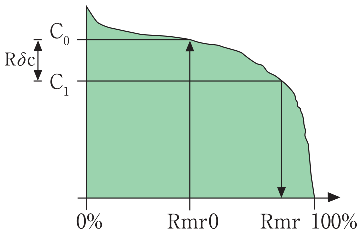
Relative material ratio (Rmr)

Rmr indicates the material ratio determined by the difference Rδc between the referential section height level Co and the profile section height level.

- **Pmr** The relative material length rate of the primary profile
- **Wmr** The relative material length rate of the waviness profile

$$\mathrm{Rmr} = \mathrm{Rmr}(c_1)$$

$$\text{Where}\quad C_1 = C_0 - R\delta c,\ C_0 = C(\mathrm{Rmr0})$$

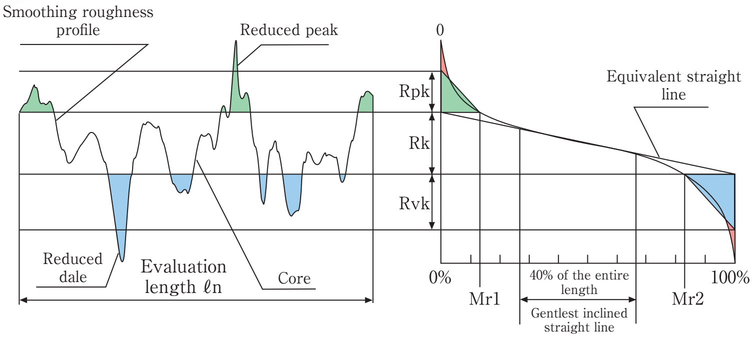


(In the case of roughness profile)

Profile method (linear roughness) parameters

Parameters of surface having stratified functional properties

Rk, Mr1, and Mr2 values are calculated from the linear curve (equivalent linear curve) minimizing the sectional inclination corresponding to 40% of the material ratio curve.
Draw a triangle with the area equivalent to the protrusion of the material ratio curve segmented by the breadth of the parameter Rk and calculate parameters Rpk and Rvk.



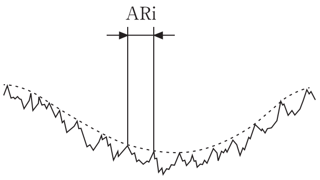
●**Rk**	Core roughness depth
●**Rpk**	Reduced peak height
●**Rvk**	Reduced valley depth
●**Mr1, Mr2**	Material portion

POINT This function is used to evaluate friction and abrasion.
It is also used to evaluate the lubricity of engine cylinder surfaces.

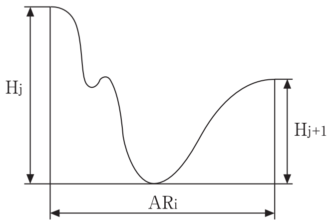
Motif parameters

Motif parameters are used for the evaluation of surface contact status based on the enveloped features of the sample surface.

●**AR**	Mean spacing of roughness motifs: the arithmetic mean of roughness motifs ARi calculated from the evaluation length
●**R**	Mean depth of roughness motifs: the arithmetic mean of the roughness motif depth Hj calculated from the evaluation length
●**Rx**	Maximum depth of roughness motifs: the maximum value of the Hjcalculated from the evaluation length
●**AW**	Mean spacing of waviness motifs: the arithmetic mean of the waviness motif AWi calculated from the evaluation length
●**W**	Mean depth of waviness motifs: the arithmetic mean of the waviness motif depth HWj calculated from the evaluation length
●**Wx**	Maximum depth of waviness motifs: the maximum value of the HWjcalculated from the evaluation length



Roughness motif



POINT These parameters are suited to evaluating the slippage of lubrication mechanisms and contact surfaces, such as gaskets.

Areal Method Parameters

Height Parameters (ISO25178-2:2012)	Symbol	Units (Default)	Page
Maximum height	Sz	µm	P.29
Maximum peak height	Sp	µm	P.29
Maximum pit depth	Sv	µm	P.29
Arithmetical mean height	Sa	µm	P.30
Root mean square height	Sq	µm	P.30
Skewness	Ssk	(Unitless)	P.31
Kurtosis	Sku	(Unitless)	P.31
Spacial parameters (ISO25178-2:2012)			
Autocorrelation length	Sal	µm	P.32
Texture aspect ratio	Str	(Unitless)	P.32
Hybrid parameters (ISO25178-2:2012)			
Root mean square gradient	Sdq	(Unitless)	P.32
Developed interfacial area ratio	Sdr	%	P.32
Functions and related parameters (ISO25178-2:2012)			
Core height	Sk	µm	P.33
Reduced peak height	Spk	µm	P.33
Reduced valley height	Svk	µm	P.33
Material ratio	Smr1	%	P.33
Material ratio	Smr2	%	P.33
Peak extreme height	Sxp	µm	P.34
Dale void volume	Vvv	ml m^{-2} (=$\mu m^3/\mu m^2$)	P.34
Core void volume	Vvc	ml m^{-2} (=$\mu m^3/\mu m^2$)	P.34
Peak material volume	Vmp	ml m^{-2} (=$\mu m^3/\mu m^2$)	P.34
Core material volume	Vmc	ml m^{-2} (=$\mu m^3/\mu m^2$)	P.34
Miscellaneous parameter (ISO25178-2:2012)			
Texture direction	Std	degrees	P.35
Feature parameters (ISO25178-2:2012)			
Density of peaks	Spd	mm^{-2}	P.35
Arithmetic mean peak curvature	Spc	mm^{-1}	P.35
Ten-point height of surface	S10z	µm	P.36
Five-point peak height	S5p	µm	P.36
Five-point pit height	S5v	µm	P.36

Areal Method Parameters

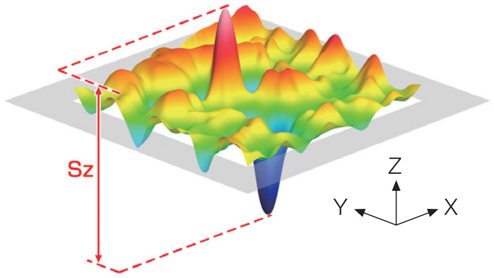
Height parameters

Maximum height (Sz)

This parameter expands the profile (line roughness) parameter Rz three dimensionally.
The maximum height Sz is equivalent to the sum of the maximum peak height Sp and maximum valley depth Sv.

POINT Although frequently used, this parameter is significantly influenced by scratches, contamination, and measurement noise due to its utilization of peak values.

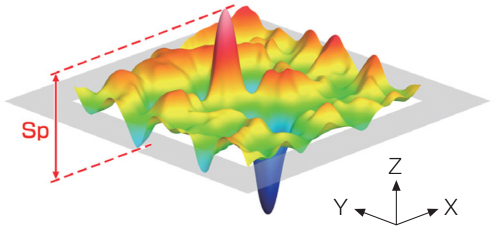
$$Sz=Sp+Sv$$



Maximum peak height (Sp)

This parameter expands the profile (line roughness) parameter Rp three dimensionally.
It is the maximum value for peak height.

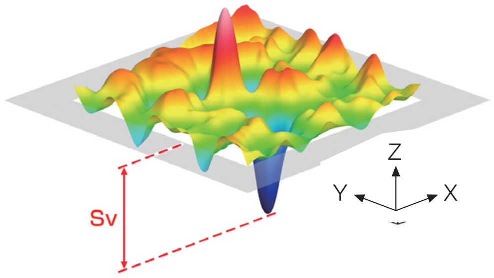
$$Sp=\max\left(Z(x,y)\right)$$



Maximum pit depth (Sv)

This parameter expands the profile (line roughness) parameter Rv three dimensionally.
It is the maximum value for the valley's depth.

$$Sv=\left|\min\left(Z(x,y)\right)\right|$$



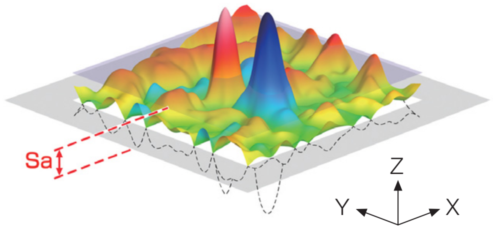
Arithmetical mean height (Sa)

This parameter expands the profile (line roughness) parameter Ra three dimensionally.
It represents the arithmetic mean of the absolute ordinate Z (x, y) within the evaluation area.

POINT

This is one of the most widely used parameters and is the mean of the average height difference for the average plane. It provides stable results since the parameter is not significantly influenced by scratches, contamination, and measurement noise.

$$Sa = \frac{1}{A}\iint_A |Z(x,y)|\,dxdy$$



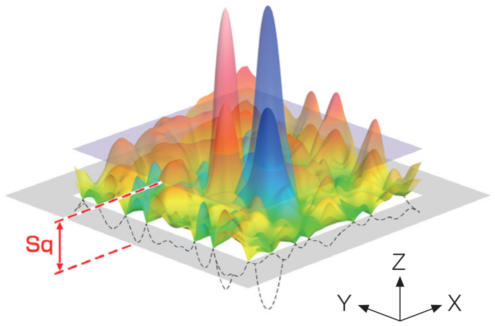
Root mean square height (Sq)

This parameter expands the profile (line roughness) parameter Rq three dimensionally. It represents the root mean square for Z(x, y) within the evaluation area.

POINT

This is one of the most widely used parameters and is also referred to as the RMS value. The parameter Rq corresponds to the standard deviation of the height distribution. The parameter generates good statistics and enables stable results since the parameter is not significantly influenced by scratches, contamination, and measurement noise.

$$Sq = \sqrt{\frac{1}{A}\iint_A Z^2(x,y)\,dxdy}$$



Areal Method Parameters

Height Parameters

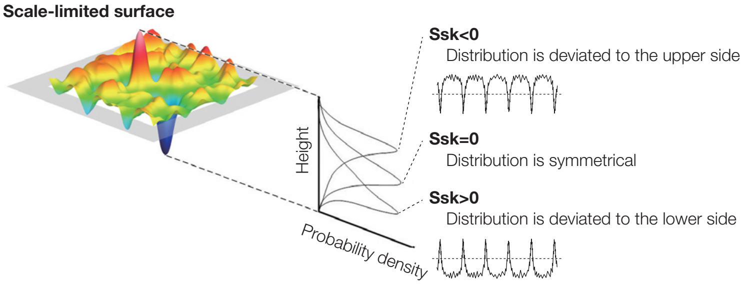
Skewness (Ssk)

This parameter expands the profile (line roughness) parameter Rsk three dimensionally; parameter Rsk, is used to evaluate deviations in the height distribution.

Ssk=0: Symmetric against the mean line
Ssk>0: Deviation beneath the mean line
Ssk<0: Deviation above the mean line

POINT This parameter concerns the height distribution and is suitable for evaluating the abrasion and oil sump of lubricants for slide planes.

$$Ssk = \frac{1}{Sq^3}\left(\frac{1}{A}\iint_A Z^3(x,y)dxdy\right)$$



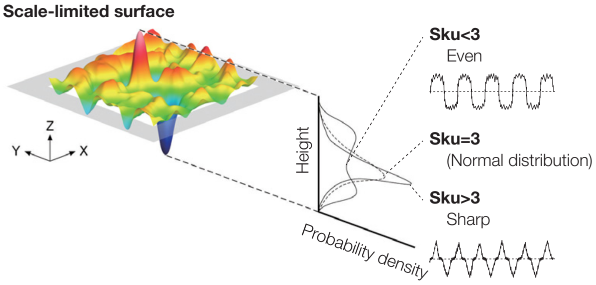
Kurtosis (Sku)

This parameter expands the profile (line roughness) parameter Rku three dimensionally; Rku, is used to evaluate sharpness in the height distribution.

Sku=3: Normal distribution
Sku>3: Height distribution is sharp
Sku<3: Height distribution is even

POINT This parameter relates to the tip geometry of peaks and valleys and is suited to analyzing the contact between two objects.

$$Sku = \frac{1}{Sq^4}\left(\frac{1}{A}\iint_A Z^4(x,y)dxdy\right)$$



Spatial parameters

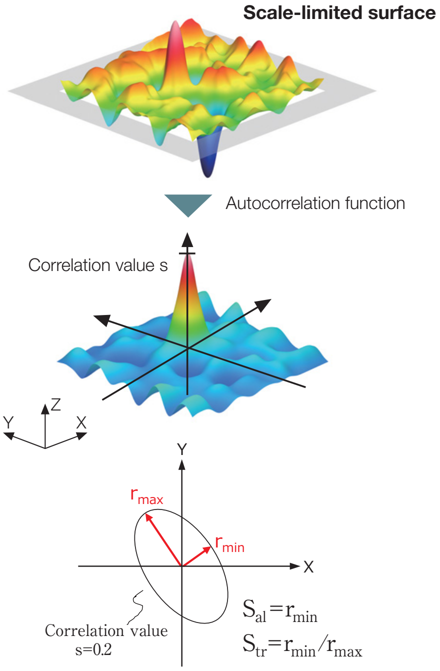
Autocorrelation length (Sal)

The horizontal distance of the autocorrelation function that has the fastest decay to a specified value s (0≤ s < 1). Unless otherwise specified, the parameter is specified as = 0.2.

Texture aspect ratio (Str)

This parameter is defined as the ratio of the horizontal distance of the autocorrelation function that has the fastest decay to a specified value s to the horizontal distance of the autocorrelation function that has the slowest decay to s (0 ≤ s < 1) and indicates the isotropic/anisotropic strength of the surface.
The Str value ranges from 0 to 1; normally Str > 0.5 indicates a strong isotropy while Str < 0.3 is strongly anisotropic.

POINT These parameters are used to evaluate the horizontal size and complexity of parallel grooves and grains instead of the height parameters.



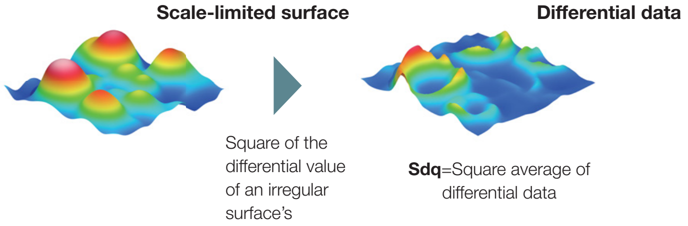
Hybrid parameters

Root mean square gradient (Sdq)

This parameter expands the profile (line roughness) parameter Rdq three dimensionally.
It indicates the mean magnitude of the local gradient (slope) of the surface.
The surface is more steeply inclined as the value of the parameter Sdq becomes larger.

POINT The steepness of the surface can be numerically represented in this parameter.

$$Sdq = \sqrt{\frac{1}{A}\iint_A \left[\left(\frac{\partial z(x,y)}{\partial x}\right)^2+\left(\frac{\partial z(x,y)}{\partial y}\right)^2\right]dxdy}$$

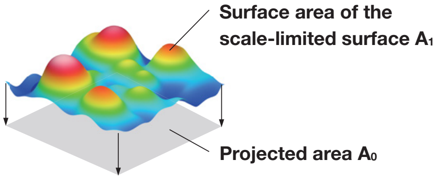


Developed interfacial area ratio (Sdr)

This signifies the rate of an increase in the surface area. The increase rate is calculated from the surface area A_1 derived by the projected area A_0.

POINT Sdr values increase as the surface texture becomes fine and rough.

$$Sdr = \frac{1}{A}\left[\iint_A\left(\sqrt{\left[1+\left(\frac{\partial z(x,y)}{\partial x}\right)^2+\left(\frac{\partial z(x,y)}{\partial y}\right)^2\right]}-1\right)dxdy\right]$$



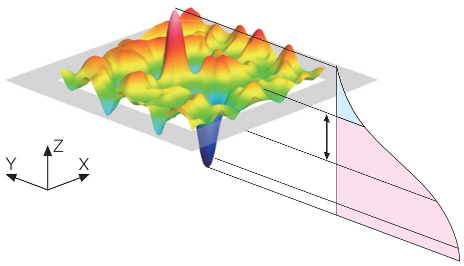
Sdr$=\{(A_1/A_0)-1\}\times 100(\%)$

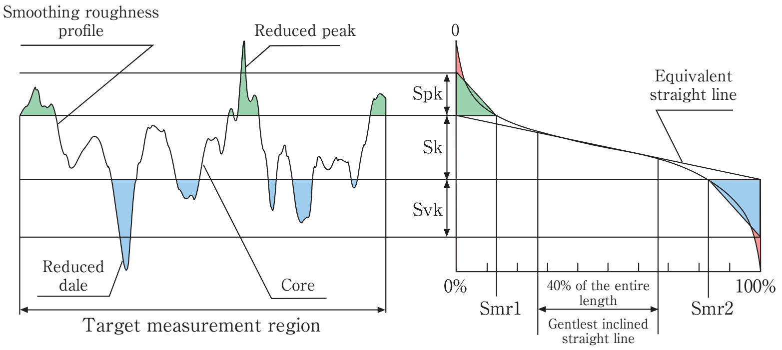
Areal Method Parameters

Function and related parameters

This parameter expands the material ratio curve parameters (Rk, Rpk, Rvk, Mr1, and Mr2) of the profile parameter three dimensionally.

●**Sk**	Core height: the difference between the upper and lower levels of the core
●**Spk**	Reduced peak height: the mean height of the protruding peaks above the core
●**Svk**	Reduced valley height: the mean height of the protruding dales beneath the core
●**Smr1**	The areal material ratio segmenting protruding peaks from the core (indicated as a percentage)
●**Smr2**	Areal material ratio segmenting protruding valleys from the core (indicated as percentage)

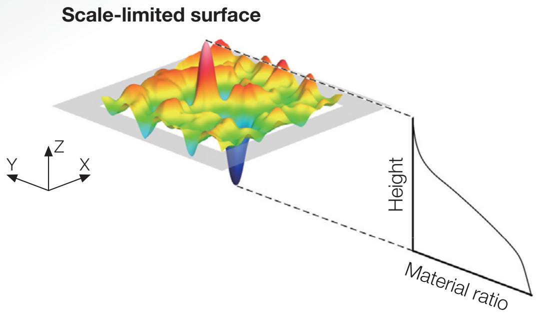


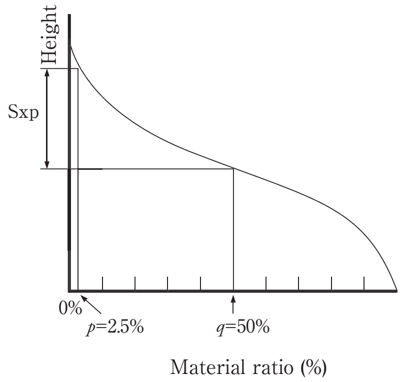


POINT This parameter is suitable for evaluating friction and abrasion. It is also used to evaluate lubricity for engine cylinder surfaces.

Peak extreme height (Sxp)

The difference in height between the p and q material ratio.
Unless specified otherwise, the values p=2.5%, q=50% shall be applied.

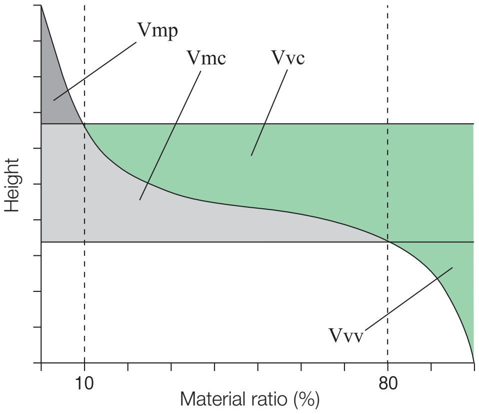




The material volume and void volume are calculated from a material ratio curve as indicated in the diagram. The position that corresponds to a material ratio of 10% and 80% is regarded as the threshold segmenting the peak, core, and dale.

●**Vvv**	Dale void volume
●**Vvc**	Core void volume
●**Vmp**	Peak material volume
●**Vmc**	Core material volume

POINT This parameter is often used to evaluate abrasion and lubricant retention.



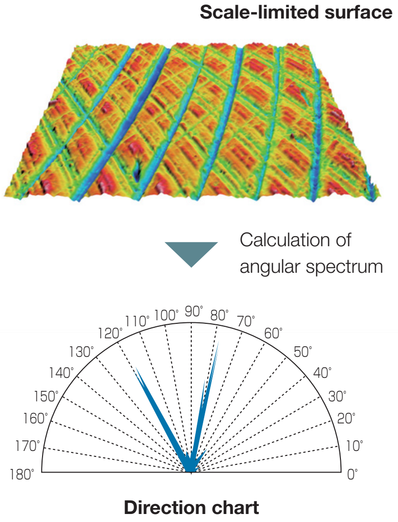
Areal Method Parameters

Miscellaneous parameters

Texture direction (Std)

This parameter indicates the direction angle of the texture (parallel groove orientation, etc.). It is derived from the angle maximizing the angle spectrum of two-dimensional Fourier transformation images.

POINT Std represents the angle for the strongest orientation, although the second and third strongest angles can also be defined on the directional chart.



Feature parameters

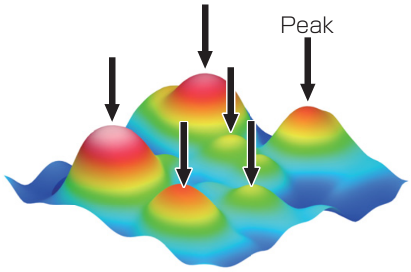
Density of peaks (Spd)

This is the number of peaks per unit area. Only peaks that exceed a designated size are counted.
Unless otherwise specified, the designated size is determined to be 5% of the maximum height Sz.
The parameter is calculated from the number of peaks divided by the projected area.

Arithmetic mean peak curvature (Spc)

Spc indicates the mean principle curvature (average sharpness) of the peaks. Only peaks that exceed a designated curvature are taken into consideration.
Unless otherwise specified, the designated size is determined to be 5% of the maximum height S_z.
The parameter is derived from the arithmetic mean curvatures of peaks within the evaluation area.

POINT This parameter is suited for analyzing the contact between two objects.



Ten-point height of surface

The average value of the heights of the five peaks with the largest global peak height added to the average value of the heights of the five pits with the largest global pit height.

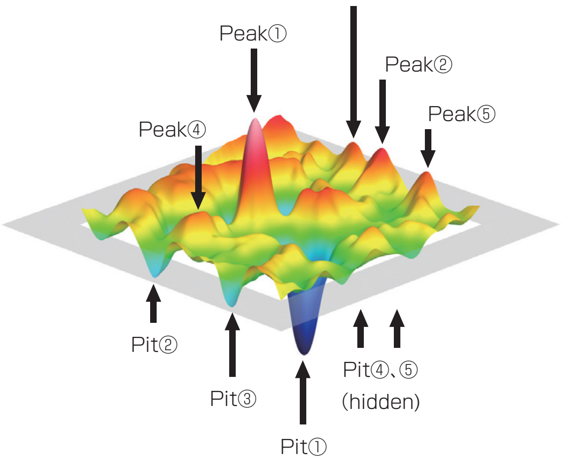
Five-point peak height (S5p)

The average value of the heights of the five peaks with the largest global peak height.

Five-point pit height (S5v)

The average value of the heights of the five pits with the largest global pit height.

$$S10z = S5p + S5v$$



Laser microscope solution

Advantages over conventional stylus roughness measurement instruments

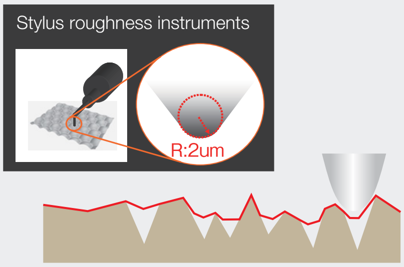
Finer roughness measurements

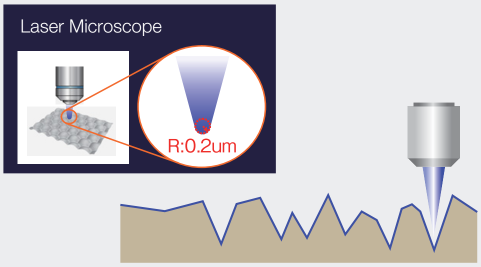
Issues

The tip radius of ordinary stylus probes is 2 to 10 µm, making it difficult to capture micro-roughness.

Solutions

The tip radius of laser microscopes is much smaller (only 0.2 µm) and enables surface roughness measurement of fine irregularities that are unreachable using stylus probes.





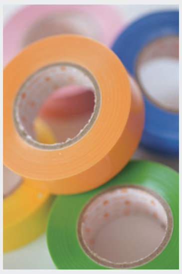
Non-contact roughness measurement

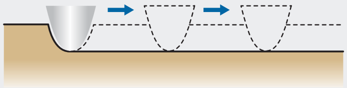
Issues

Stylus instruments require direct contact between the probe and sample surface. This may cause the probes to scrape soft sample features or strain samples that have adhesive properties, making it difficult to obtain accurate data.

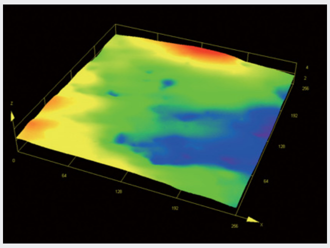
Solutions

Laser microscopes acquire information without touching the sample, making them capable of taking accurate roughness measurements regardless of the sample's surface.





Stylus probes may damage the sample surface



Laser microscope observation image
Sample: Adhesive tape
256×256µm

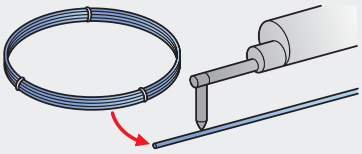
Local region roughness measurement

Issues

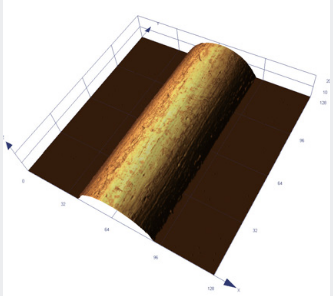
A contact stylus is not good at taking measurements from restricted areas, such as very small wires.

Solutions

Laser microscopes function on a planar basis, and the image-based precision positioning capability enables easy roughness measurement of minute targeted areas.



Lowering stylus probes onto the surface of wires several dozen microns across is extremely difficult to accomplish



Observation image obtained with laser microscopes
Sample: Extra fine wire ϕ50µm

Advantages over coherence scanning interferometers

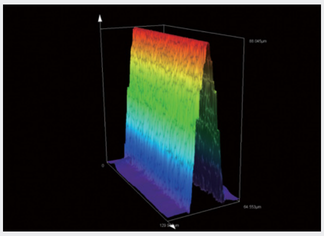
Steep slope detection performance

Issues

Although whiteness interferometers maintain subnano level detection sensitivity for smooth surfaces, the congestion of interference patterns prevents accurate measurement of steeply inclined surfaces (rough sur- faces).

Solutions

With high NA dedicated objective lenses and 405 nm lasers, the laser microscope provides accurate measurements of samples with of steep, angled surfaces.



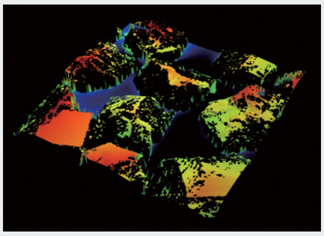
Capable of measuring low-reflection surfaces

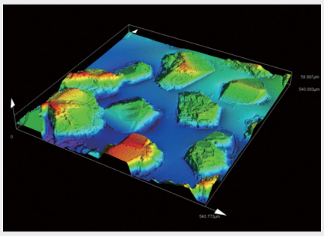
Issues

CCD and other types of imaging sensors in whiteness interferometers tend to pass over weak signals depending on the condition of the sample's surface, making it difficult to take accurate measurements.

Solutions

The high sensitivity light detectors (photo multipliers) used in a laser microscope maintain a high S/N ratio, providing accurate measurements of sample surfaces with low-reflectivity.





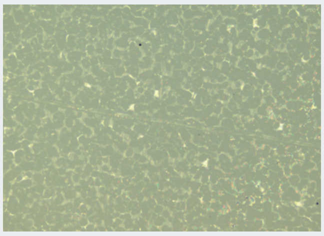
High horizontal resolution

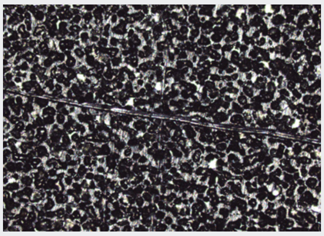
Issues

The NA of the interference objective lens on whiteness interferometers is smaller than that used on optical microscopes and has lower horizontal resolution. Unlike optical microscopes, clear, live sample observation is difficult for interferometers.

Solutions

Laser microscopes are equipped with both color optics and laser confocal optics, offering clear, high resolution images to observe microscopic scratches and fine positioning.





Laser microscope solution

Advantages over scanning probe microscopes (SPM)

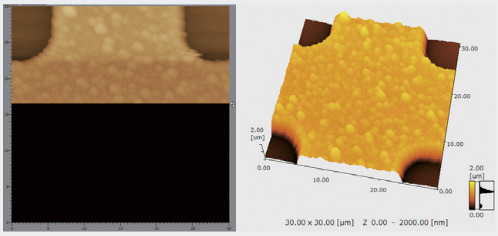
Fast, precise 3D measurement

Issues

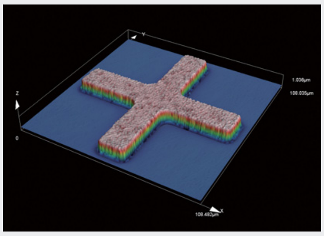
Although SPMs are capable of sub-nano level feature measurement, the cantilever-based scanning of the sample surface is a time-consuming process.

Solutions

The high-speed horizontal laser scanning of laser microscopes enables sub-micron level feature data to be acquired quickly.



About 850 seconds



About 15 seconds

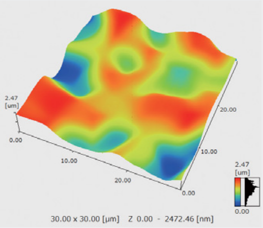
Wide field measurement

Issues

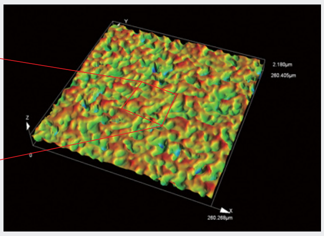
The scan area for SPMs is confined to small areas of about 100 μm and is not suitable for measuring large features and low magnification observation.

Solutions

Laser microscopes are capable of observing sub-micron irregularities using a field of view much broader than SPMs. The horizontal stitching capabilities further expand the area of analysis.



Scanning probe microscope



Laser microscope

Laser microscope solution

Advantages over digital microscopes

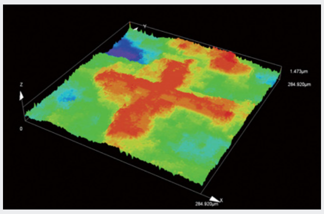
Accurate, precise 3D measurement

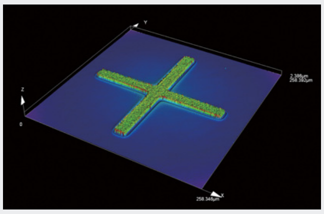
Issues

Digital microscopes are not suitable for acquiring information of delicate sub-micron surface features.

Solutions

The laser-based scanning of the sample surface enables laser microscopes to accurately acquire delicate surface features.





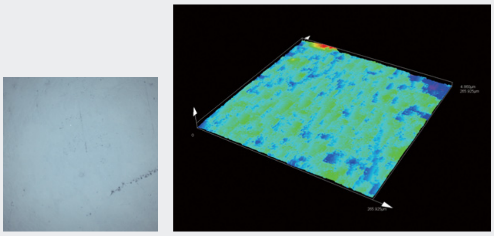
Capable of measurement regardless of the sample (this could be clearer)

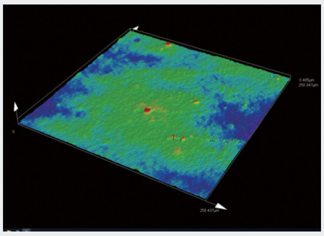
Issues

Digital microscopes construct the configuration data using the contrast information acquired from the sample surface. Because of this, they are not suitable for observing low-contrast polished surfaces and smooth films.

Solutions

The confocal optics incorporated in laser microscopes accurately capture surface features without being influenced by the sample's surface condition.





Advantages of the OLS5100 3D laser scanning confocal microscope for surface roughness measurement

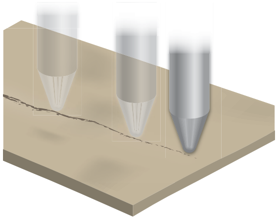
OLS5100 microscope characteristics

Characteristics 1 Non-contact, nondestructive, and fast

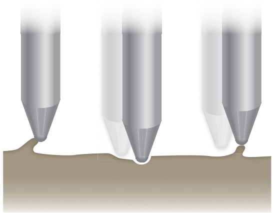
No preliminary preparation required. Simply place the sample on the stage and begin measurement.

Roughness gage

Sample damage

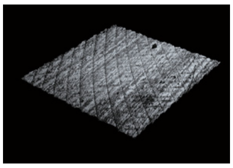


Adhesive samples are not measurable

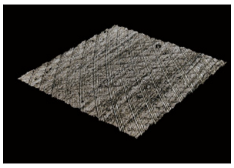


Characteristics 2 Comprehensive sample information

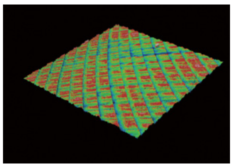
Three types of information are acquired simultaneously



Laser image



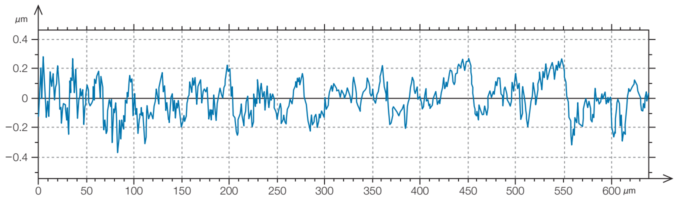
Color image



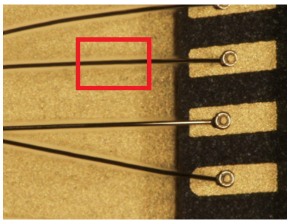
3D feature data

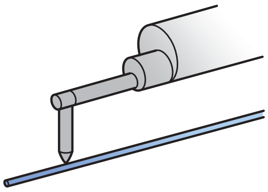
Roughness gage

Observation for a single profile only



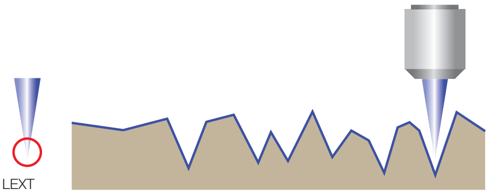
Difficult to precisely position





Characteristics 3 Captures fine irregularities

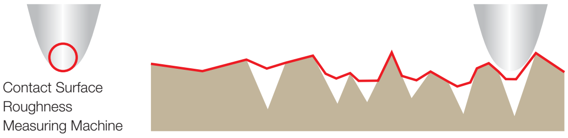
The 405 nm / 0.4 µm diameter laser beam scans fine features without distortion.



LEXT
OLS5100
R: 0.2µm

Roughness gage

The stylus cannot measure features smaller than the tip of the probe



Contact Surface
Roughness
Measuring Machine
R: 2µm

OLS5100 Example of measurement 1

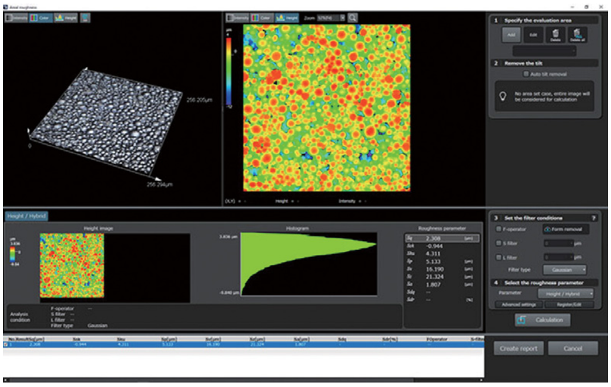
Measuring the Roughness of Lithium-Ion Battery Electrodes

Lithium-ion batteries charge and discharge because their lithium ions can move in both directions between positive and negative electrodes. Until recently, they had been mainly used in compact form in PCs, mobile phones, and digital cameras, but the demand is increasing for lithium-ion batteries with an electric capacity that is large enough for electric vehicles (EVs).

Surface Roughness Checks of Electrode

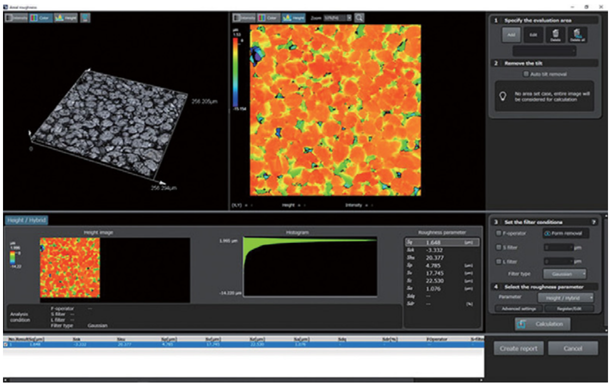
The electrode material on the sheet needs to have proper surface roughness to securely adhere to the separator. For this reason, surface roughness measurement using a roughness measuring instrument is necessary. There are various types of surface roughness measuring instruments, but to accurately measure the surface roughness of electrodes, the options are limited. With contact-type roughness gages there is a risk of damaging the electrode surface, while interferometers are unreliable because the black electrodes absorb the light they use for measurement.
OLS5100 is the noncontact measurement method eliminates the risk of damaging the electrodes as well as collateral data errors. Even though electrodes are black and have a very low light reflectivity, only a minute amount of reflected light needs to be captured to acquire the required data. Using an optical system exclusive to laser microscopes, the LEXT OLS5100 microscope enables you to acquire data that is accurate to the center of the field of view as well as the area around it. Various kinds of data can be stitched horizontally, enabling acquisition of surface roughness data for a wide area.

Example of roughness measurement of a positive electrode



Roughness parameter
Sq 2.308 [μm]
Ssk -0.944
Sku 4.311
Sp 5.133 [μm]
Sv 16.190 [μm]
Sz 21.324 [μm]
Sa 1.807 [μm]
Sdq --
Sdr -- [%]

Example of roughness measurement of a negative electrode



Roughness parameter
Sq 1.648 [μm]
Ssk -3.332
Sku 20.377
Sp 4.785 [μm]
Sv 17.745 [μm]
Sz 22.530 [μm]
Sa 1.076 [μm]
Sdq --
Sdr -- [%]

OLS5100 Solutions

Roughness measurement using LEXT OLS5100 enables simultaneous observation of the pseudo color, 3D images, and height information of a laser microscope and real color images of an optical microscope.

Advantages of the OLS5100 3D laser scanning confocal microscope for surface roughness measurement

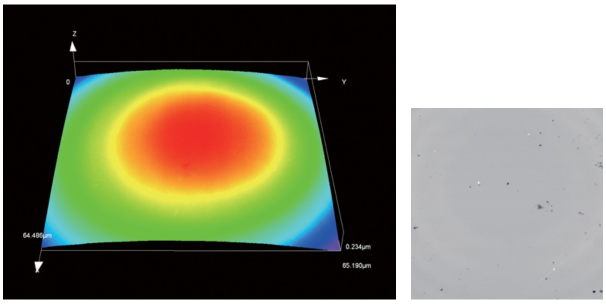
OLS5100
Example of 2
measurement

Measuring the tip of burnishing tools

Burnish processing is a method to create smooth mirror-finish surfaces by moving hemispheric burnishing tools (diamond turning tools) along the metal surface.
The tip of the burnishing tool wears out over time, influencing the smoothness of the surface being processed. It is important to manage the damage and evaluate surface roughness of the tool tips.

A comparison of the roughness of diamond tool tips from new and used tools

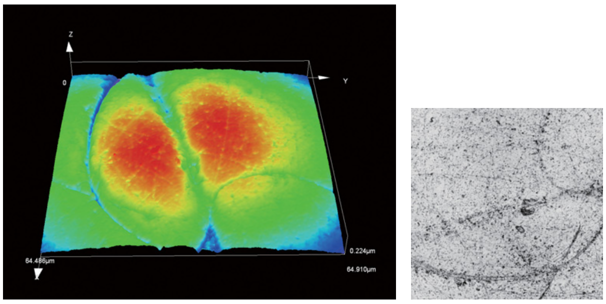
Before use



Analysis parameters

Sq	0.019 [μm]	Ssk	0.883
Sku	5.473	Sp	0.110 [μm]
Sv	0.047 [μm]	Sz	0.157 [μm]
Sa	0.014 [μm]		

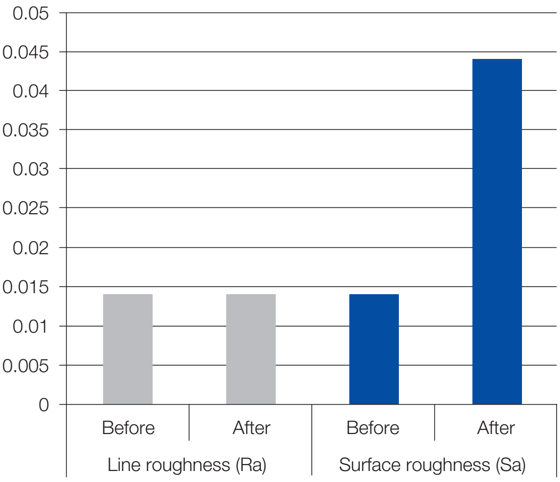
After use



Analysis parameters

Sq	0.065 [μm]	Ssk	-1.753
Sku	6.976	Sp	0.153 [μm]
Sv	0.386 [μm]	Sz	0.539 [μm]
Sa	0.044 [μm]		

Applying stylus probes from conventional roughness gages onto the $\phi 3$ mm tip of burnishing tools is difficult. Furthermore, slight wear of the tool tips cannot be captured using conventional instruments. When comparing new and used burnishing tools using the linear roughness parameter Ra, distinctive differences may be overlooked depending on the line of measurement, leading to potential errors in the determining the condition of abrasion.
By contrast, the OLS5100 confocal laser microscope bases its numerical conversion on the areal roughness parameter Sa and is capable of capturing fine irregularities on a broader scope to identify the difference between pre- and post-usage. This enables a more accurate judgment.



OLS5100 Solutions

Able to measure the surface roughness of the target area easily while observing the magnified high resolution image in a wide area.

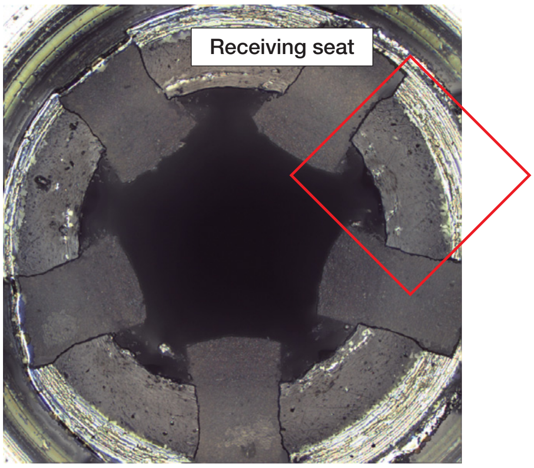
OLS5100
Example of 3
measurement

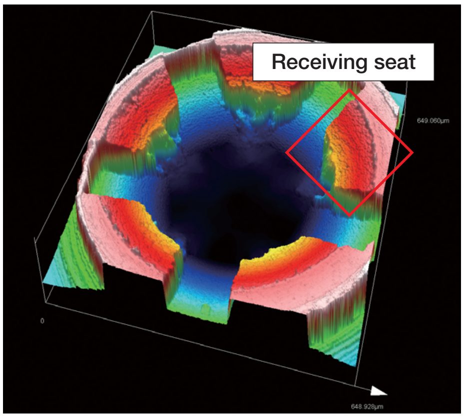
Evaluating the roughness of the receiving seat of a ball placed at the tip of a ballpoint pen

Widely used in daily activities, the condition of ballpoint pens are determined how well the ball slides while writing, the feel of the handheld pen, and the ease of operation. The surface roughness of the receiving seats holding the rotating tips are directly linked to the friction (resistance) and are, therefore, an important aspect of ballpoint pens.

Evaluating the roughness of the ball receiving seat of a ballpoint pen

Due to the small size and complex shape of receiving seats, conventional roughness gages have difficulty probing and tracing the features.
The non-contact measurement of OLS5100 microscope easily acquires fine details from the recessed portions of the seat. Contrary to single profile-based roughness gages, the large amount of data acquired from a broad area makes it possible to focus the target region for localized roughness measurement on components with complex forms. Multiple target areas can be designated, and their surface roughness and mean roughness can be easily quantified.





The roughness of the receiving seat

Sq	6.698 [μm]	Sv	23.792 [μm]
Sku	3.316	Sz	45.475 [μm]
Ssk	-0.408	Sa	5.087 [μm]
Sp	21.683 [μm]		

✓ OLS5100 Solutions

Non-contact measurement enables surface roughness measurement in recessed portions of the sample that are difficult to measure using conventional roughness gages

Advantages of the OLS5100 3D laser scanning confocal microscope for surface roughness measurement

OLS5100
Example of 4
measurement

Quantitative evaluation of the difference in skin texture

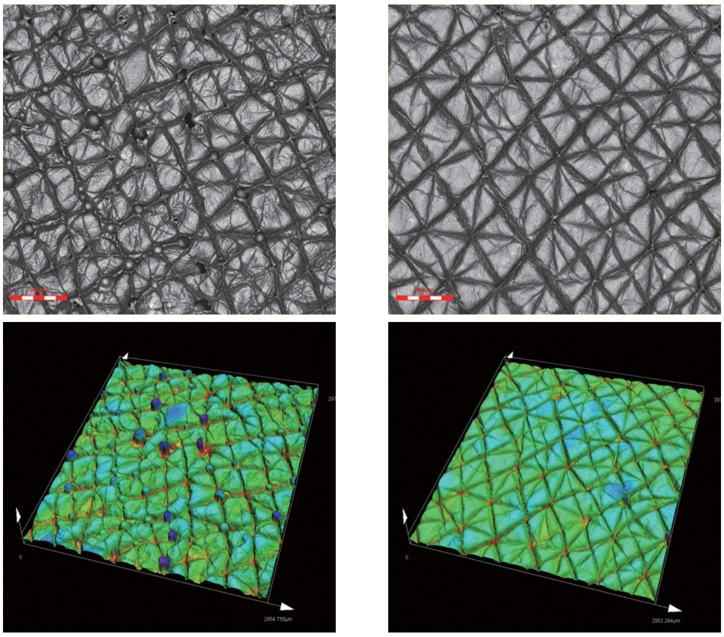
Industrial products can be enhanced in various ways. Improving the texture to impart a high-quality feel in the interior of automobiles and architectural materials are two applications where these enhancements are common. Another example is cosmetic companies, who have analyzed the texture of human skin to understand the impact cosmetics have on how the skin feels.

Quantification of skin texture

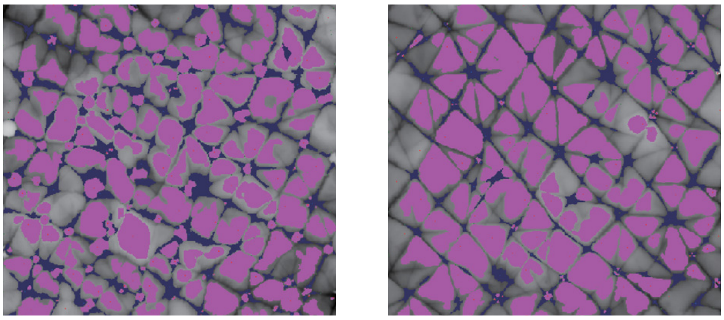
Skin texture differs among individuals. Accordingly, it is important to quantify the texture of the skin's surface.
Since conventional roughness gages evaluate texture based on a linear measurement, it is difficult to determine the overall condition of the skin. The stylus may also cause damage.
The OLS5100 microscope bases its data acquisition on planar roughness parameters like Spc and Spd (ISO25178-2), facilitating the quantification of skin texture topography including the quantity of skin bumps per unit area, the average height of skin bumps (or depth of skin depressions), and the curvature of skin bump peaks. In addition, the non-contact scanning does not harm the sample.

Subject 1 (data B)

Subject 2 (data C)



Quantification of skin texture



Peak density (Spd) 32(1/mm2)
Peak curvature (Spc) 1315(1/mm)

Peak density (Spd) 25(1/mm2)
Peak curvature (Spc) 1121(1/mm)

🟪 Skin bumps (peaks) 🟦 Skin depressions (valleys)

* Observation sample image uses an inverted replica.

* Provided by Laboratory of Department of Fashion Technology, Faculty of Fashion Science, BUNKA GAKUEN UNIVERSITY

OLS5100 Solutions

Non-contact and capable of surface roughness measurements regardless of the sample

Cited reference

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—Surface texture: Profile method type -- Glossary, definition, and surface texture parameters
JIS B0671(2013)Geometric Product characteristic Specifications (GPS)
—Surface texture: Profile method type -- Characteristics evaluation of scale-limited stratified functional surfaces
JIS B0631 (2000) Geometric Product characteristic Specifications (GPS)
—Surface texture: Profile method type -- Motif parameter
JIS B0632 (2001) Geometric Product characteristic Specifications (GPS)
—Surface texture: Profile method type -- Phase correct filter characteristics
Richard Leach, Fundamental principles of engineering nanometrology, Elsevier 2010

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