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Test Report TRACEiT®

Mobile optical surface structure analysis

Würzburg, 2012-04-17

Customer:

Samples: Filter plates

Report no.:

Test engineer:

Report by:

(sign)

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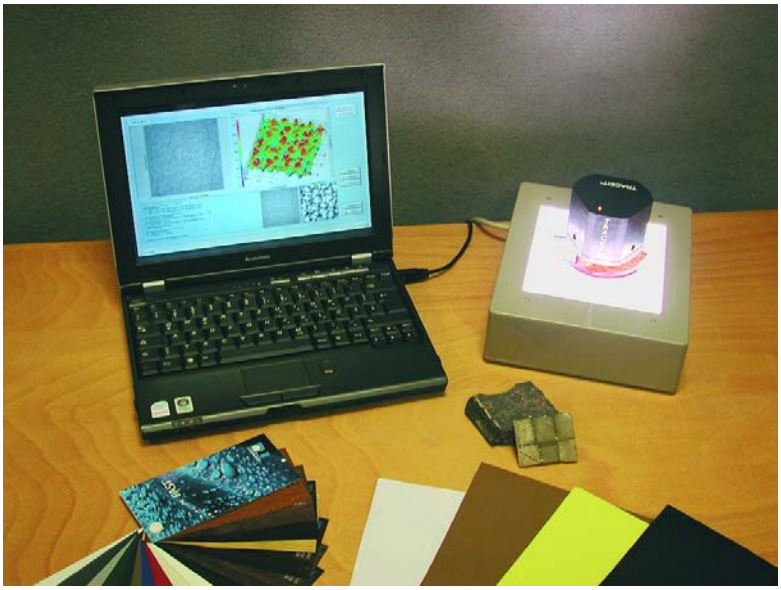
1. Principles of function TRACEiT®

The new, patented TRACEiT® system is a mobile, contact free surface documentation and analysis tool. It is the first instrument in the market to provide the visual impression as well as the 3D topography and the derived parameters like the roughness values R_a, R_q and R_z for the 3D topography or the „visual intensity“ for the visual impression. Hence with the TRACEiT® it is possible to document, analyze and evaluate the visual appearance and thus the visual impression to the human eye. The same applies to the 3D topography.

The evaluation of a surface by topographic and visual parameters happens at the same time and at the same place on the surface so it is possible to compare them for correlations or to take it into account for damage evaluation.

The measuring system consists of a sensing head connected to a special, modified notebook. All operations are processed via the interaction of measuring head and notebook. Storage, evaluation and analysis happen in the notebook. Data can be exported to other programs for further analysis. The system is independent of external power supply and other controls and allows measurements at almost any location.

Optionally, there is a transmitting light table available to investigate transparent or translucent materials like e.g. glass, foils, fabrics or paper. So among other things the system is able to measure and evaluate the cloudiness of paper.



TRACEiT with transmitting light table

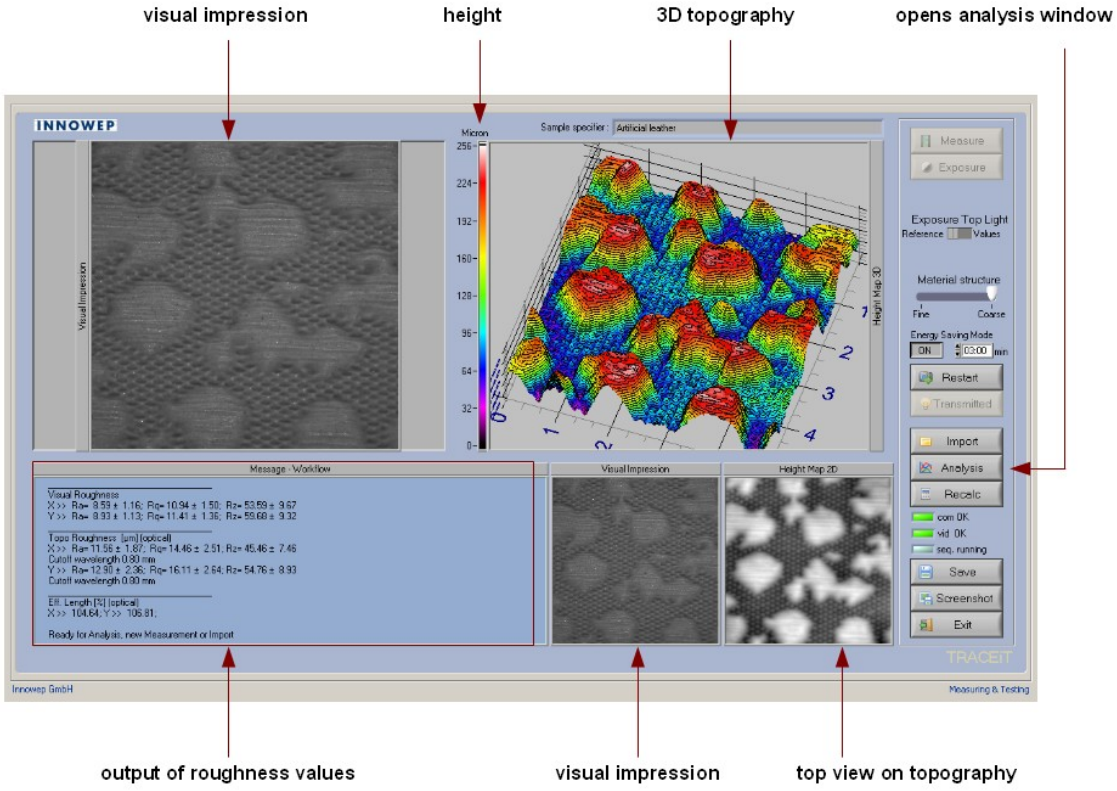
2. Documentation

The measured data is analyzed by a powerful software. In the following chapters the analysis windows are listed and explained in detail.

2.1 Total view

In the total view window the visual impression and the computed 3D topography together with the derived parameters are shown. The 3D topography is documented by the roughness parameters R_a, R_q and R_z and their standard deviations. The visual impression is documented by the „visual intensity“. The “Analysis” button opens the analysis window for the 3D topography and the visual impression. This is explained in chapter 2.2 and 2.3.

Overview main window

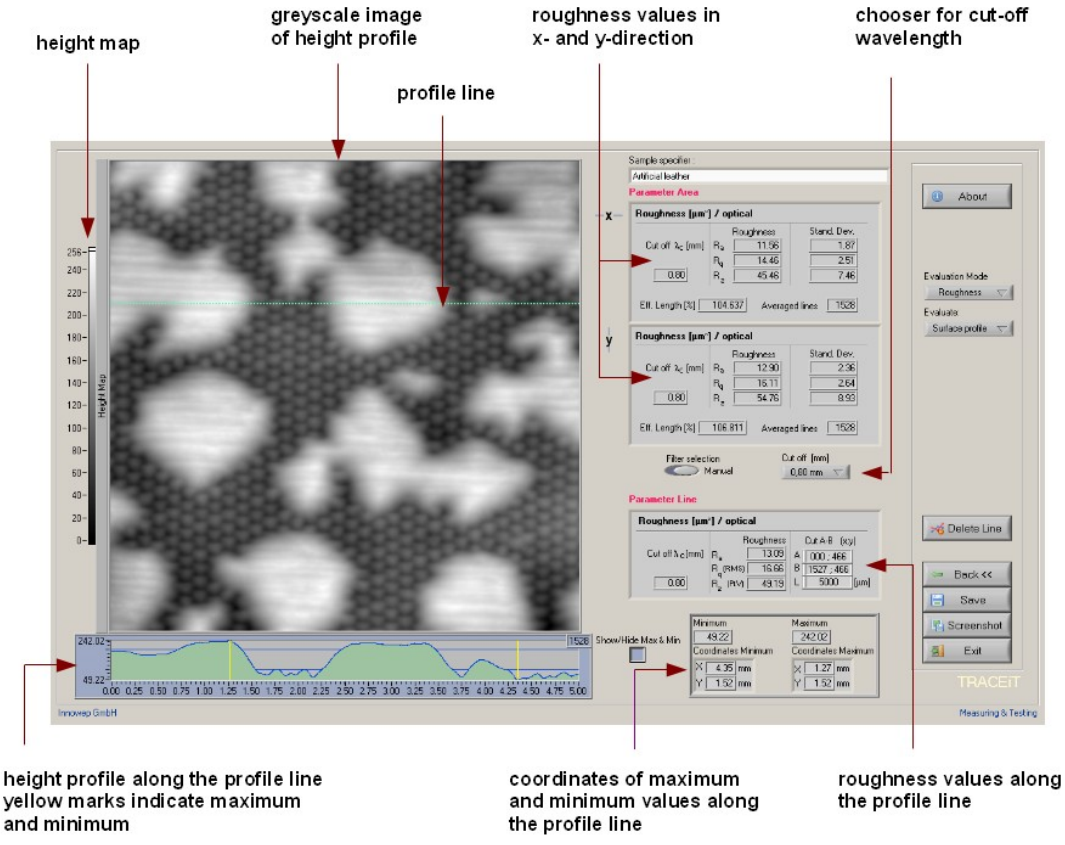


2.2 Documentation of topographic roughness

The topographic roughness can be examined in the analysis window. It contains the calculated height profile as a gray scale image map with the corresponding heights in µm. It displays the roughness parameters R_a, R_q and R_z and their standard deviations. The evaluation of the topography happens with a maximum resolution of 1528 pixels in x and y direction. The lateral resolution amounts 3 µm. The evaluation in x and y direction happen independently so that possible anisotropies can be detected and evaluated separately.

The roughness parameters in x and y direction are averaged over all 1528 lines. Additionally it is possible make line cuts in horizontal or vertical direction or with a freely drawn line. The roughness parameters are displayed while moving the mouse in the map. Below the image map the height profile of the actual cut is displayed together with the minimum and maximum values.

Overview analysis window for topographic roughness

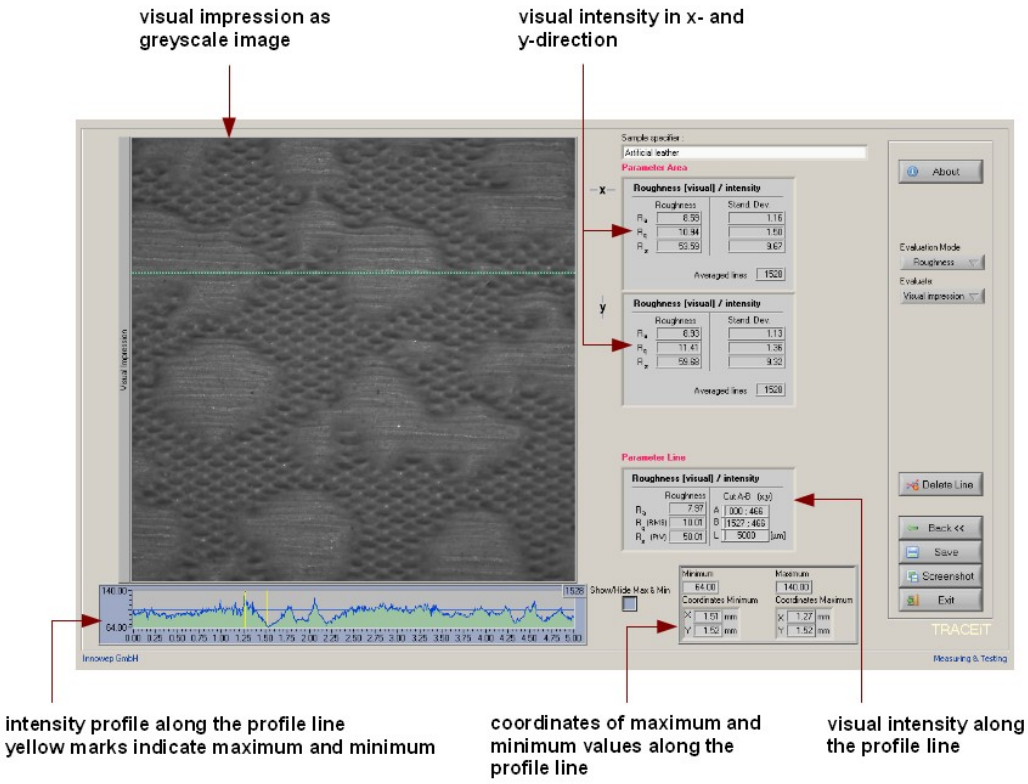


2.3 Documentation of the visual impression

The visual impression documents the appearance of a surface to the human eye. The analysis window contains an image of the measured surface in gray tones which presents the intensity stimuli to the human eye. The evaluation is done in the style of the topography but in gray tone units. Therefore the roughness parameters have no defined unit. The roughness parameters $R_{a\ opt}$, $R_{q\ opt}$ and $R_{z\ opt}$ document the bright/dark contrast of the sample.

Both, visual impression and topography measurement happen at the same time at the same place. Thus a direct comparison of topographic roughness and visual intensity is possible.

Overview analysis window of the visual impression

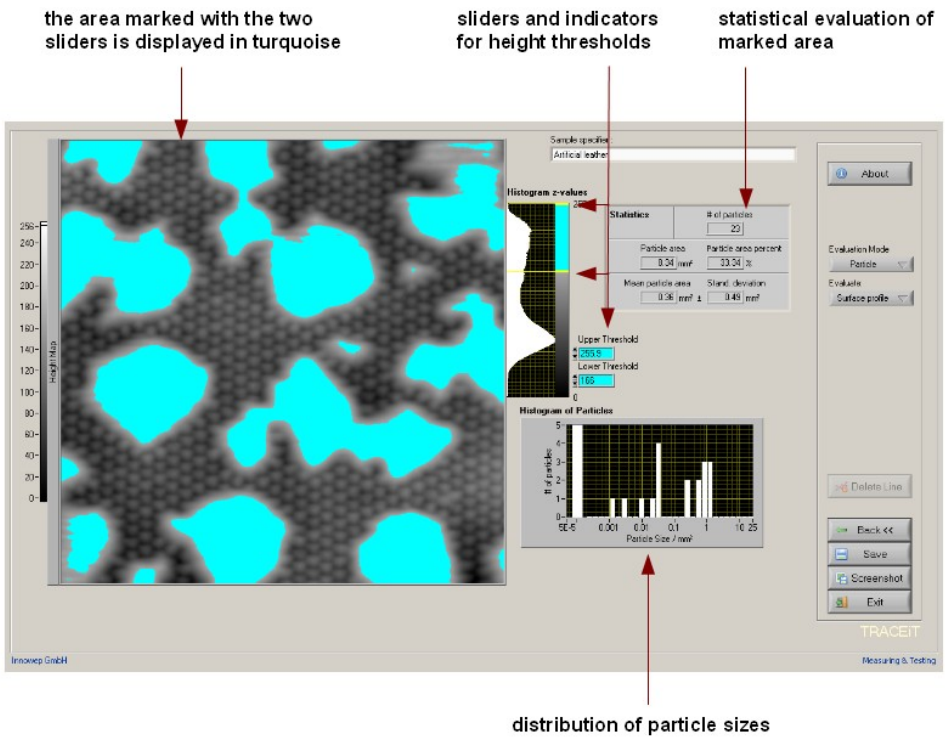


2.4 Particle mode

Besides evaluation of the surface based on roughnesses a particle mode is available. Here, the topographies can be examined regarding particle or pore distribution, effective contact area or structure by vertical sections. This is of particular interest if the contact area with other materials or the human hand shall be determined or the fraction of valleys in the structure in which dirt can accumulate. In the statistics block the system displays the total area of the particles as absolute value and as portion of the total area as well as the average particle size.

The particle mode can not only be applied to the topography but also to the visual impression and transmitted light image. This enables to evaluate e.g. the color tone (as a gray tone) of the sample or the material density through the light absorption.

Overview particle mode window



2.5 Definition of roughness parameters

Roughness is a measure of the texture of a surface. It is quantified by the vertical deviations of a real surface from its ideal form. If these deviations are large, the surface is rough; if they are small the surface is smooth. Roughness is typically considered to be the high frequency, short wavelength component of a measured surface.

Roughness plays an important role in determining how a real object will interact with its environment. Rough surfaces usually wear more quickly and have higher friction coefficients than smooth surfaces. Roughness is often a good predictor of the performance of a mechanical component, since irregularities in the surface may form nucleation sites for cracks or corrosion.

In everyday's work three roughness definitions have been established:

1. Mean Roughness (*Roughness average* R_a): R_a is the arithmetic average of the absolute values of the roughness profile ordinates. R_a is one of the most effective surface roughness measures commonly adopted in general engineering practice. It gives a good general description of the height variations in the surface.

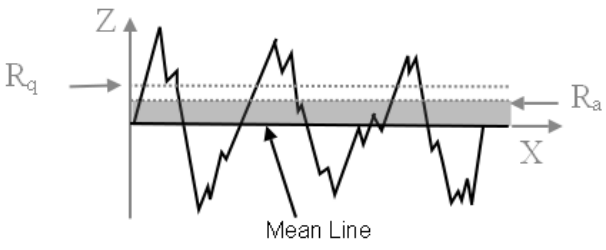
   $$R_a = \frac{1}{n}\sum_{i=1}^{n} |y_i|$$

2. The Root Mean Square (RMS) roughness (R_q): R_q is the root mean square average of the roughness profile ordinates.

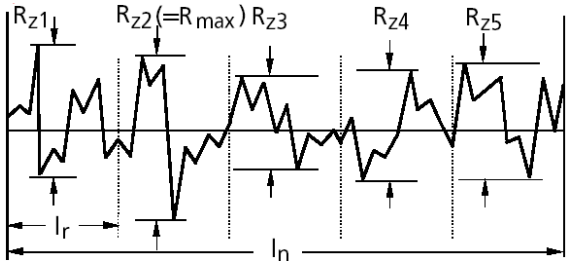
   $$R_q = \sqrt{\frac{1}{n}\sum_{i=1}^{n} y_i^2}$$

3. Mean Roughness Depth (R_z): R_z is the arithmetic mean value of the single roughness depths (the vertical distance between the highest peak and the deepest valley within a sampling length) of five consecutive sampling lengths.

   $$R_z = \frac{1}{n}(R_{z1} + R_{z2} + R_{z3} + R_{z4} + R_{z5})$$



definition of R_a and R_q



definition of R_z

In highest resolution mode the TRACEiT evaluates the roughness parameters over 1500 lines, each 5 mm in length. This summarizes to 7.50 m independently in x as well as y direction!

3. Samples and parameters

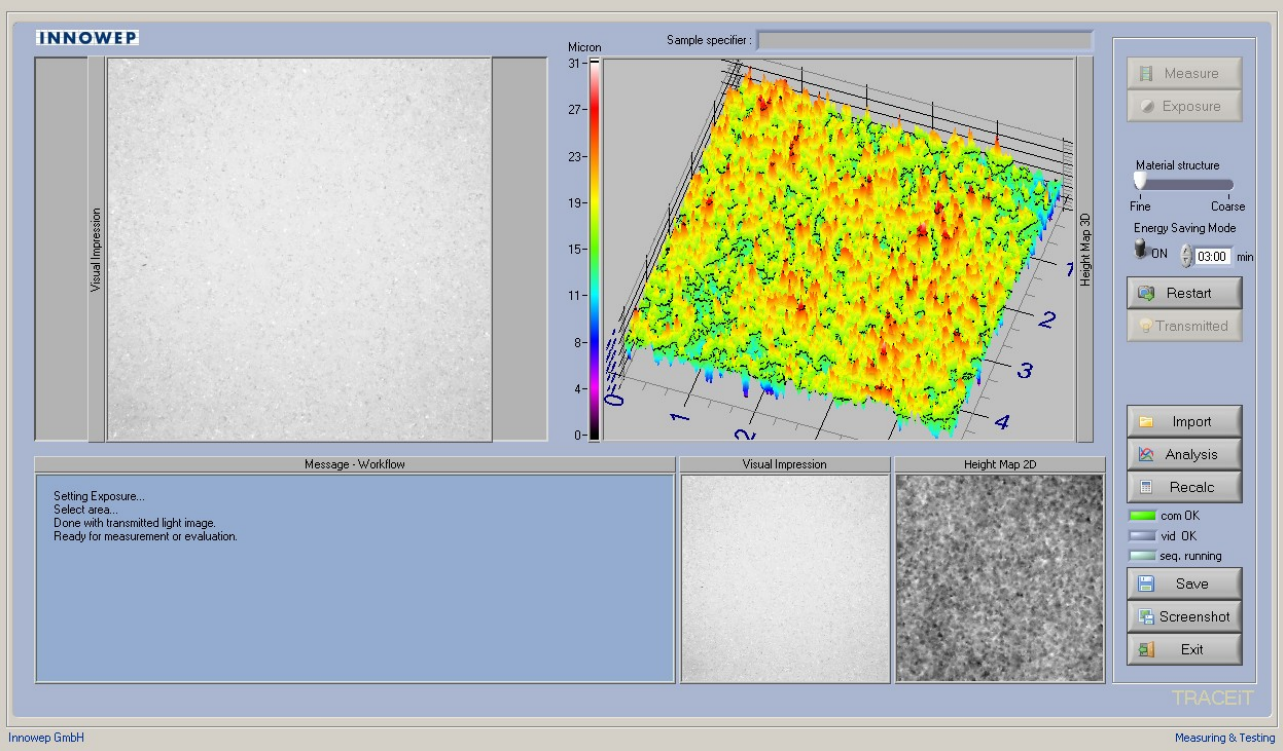
We had three filter plates which we labeled with 1, 2 and 3. The plates had a thickness of 2 mm. The task was to measure the 3D topography and hence the surface roughness.

The TRACEiT® systems surveys a standard area of 5 x 5 mm. The 3D topography was calculated with the highest resolution.

4. Results

4.1 Sample 1

Total view



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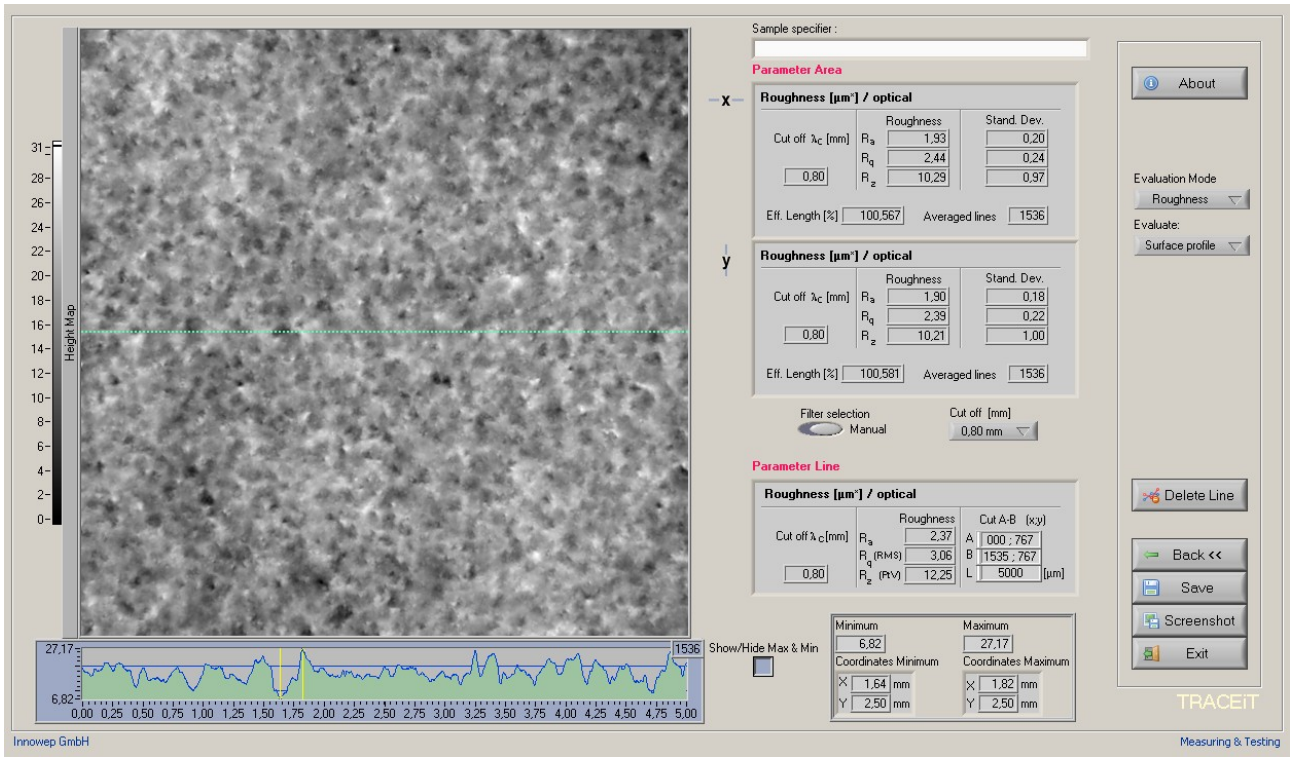
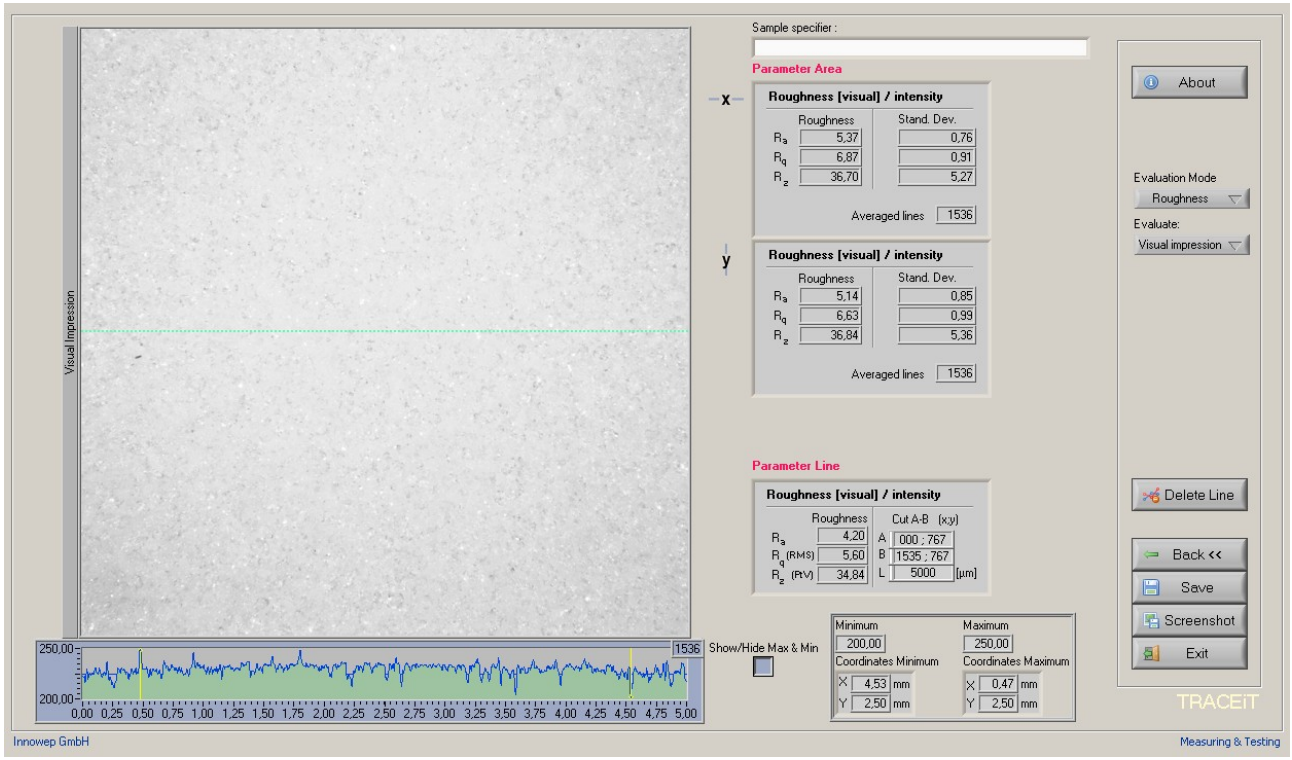
Results topography

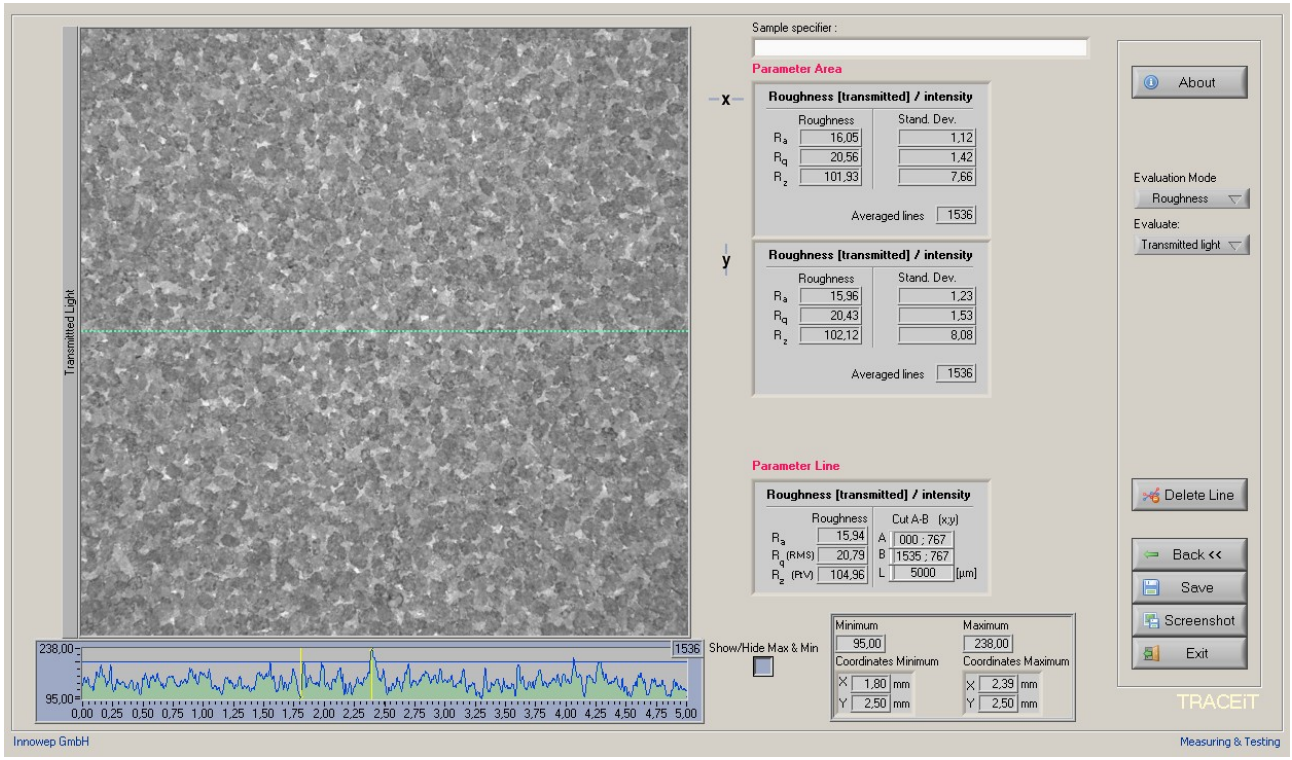


Results visual impression



The evaluation is done in the style of the topography but in gray tone units. Therefore the roughness parameters have no defined unit.

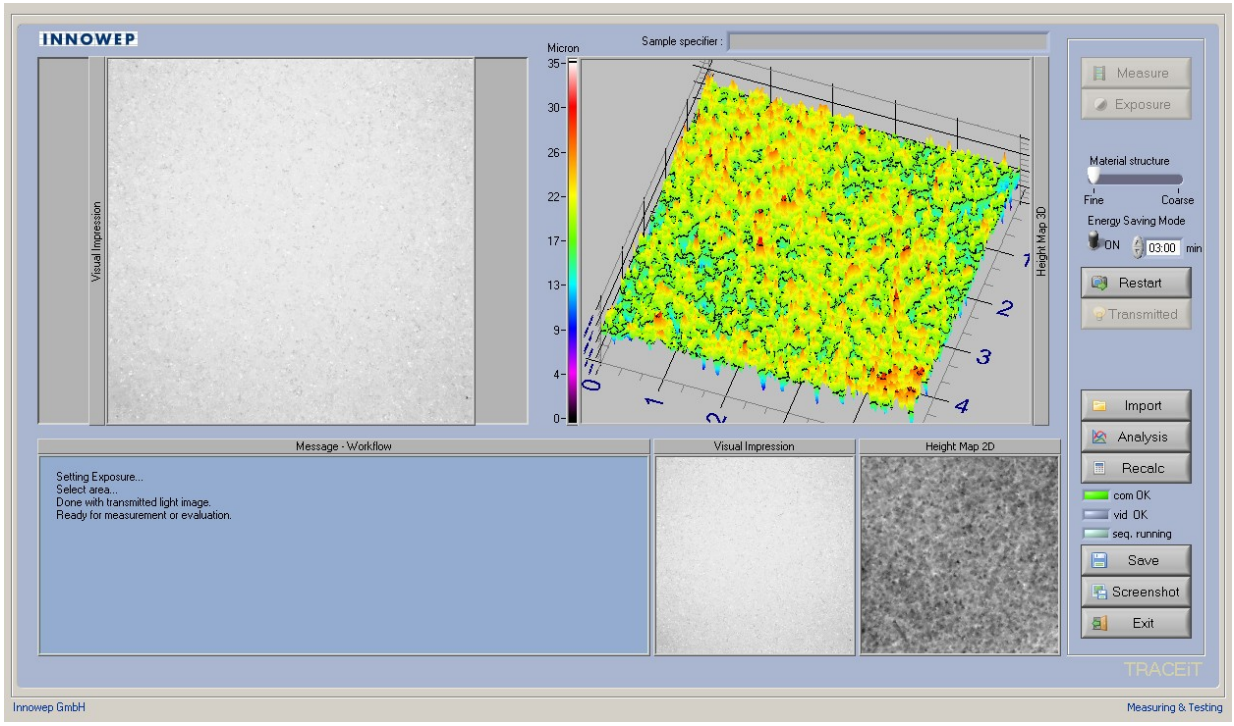
Results transmitted light mode



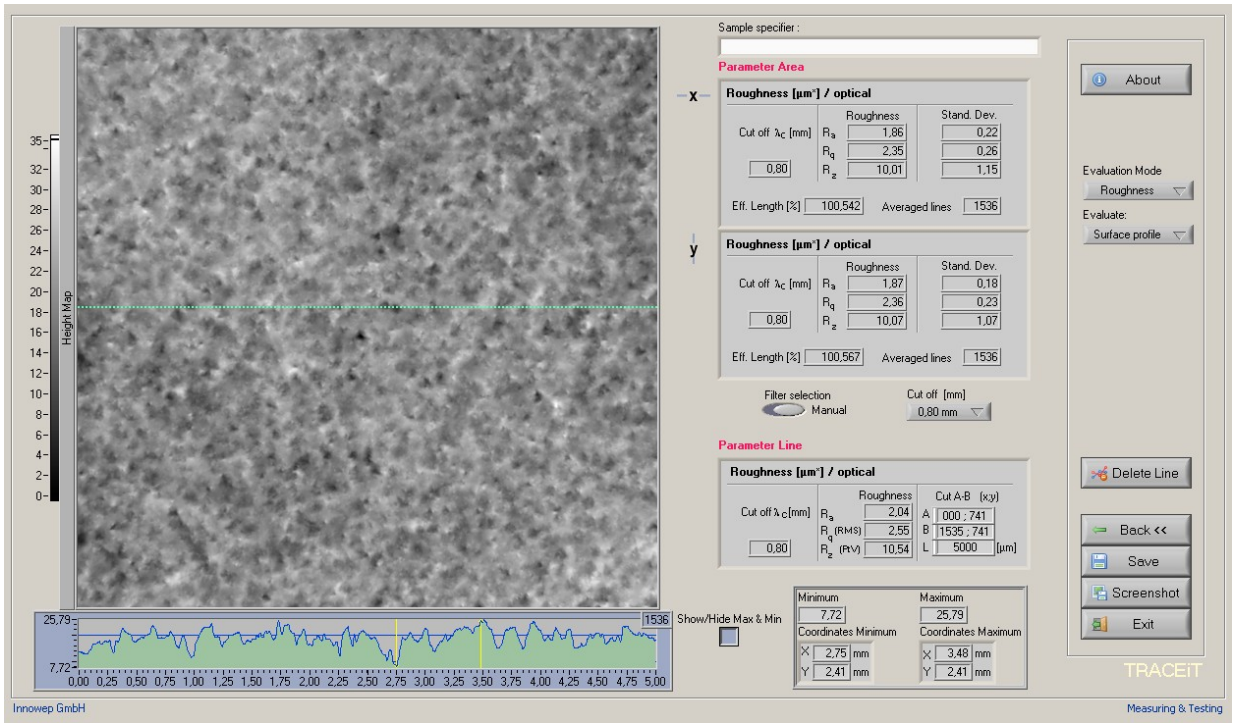
The evaluation is done in the style of the topography but in gray tone units. Therefore the roughness parameters have no defined unit.

4.2 Sample 2

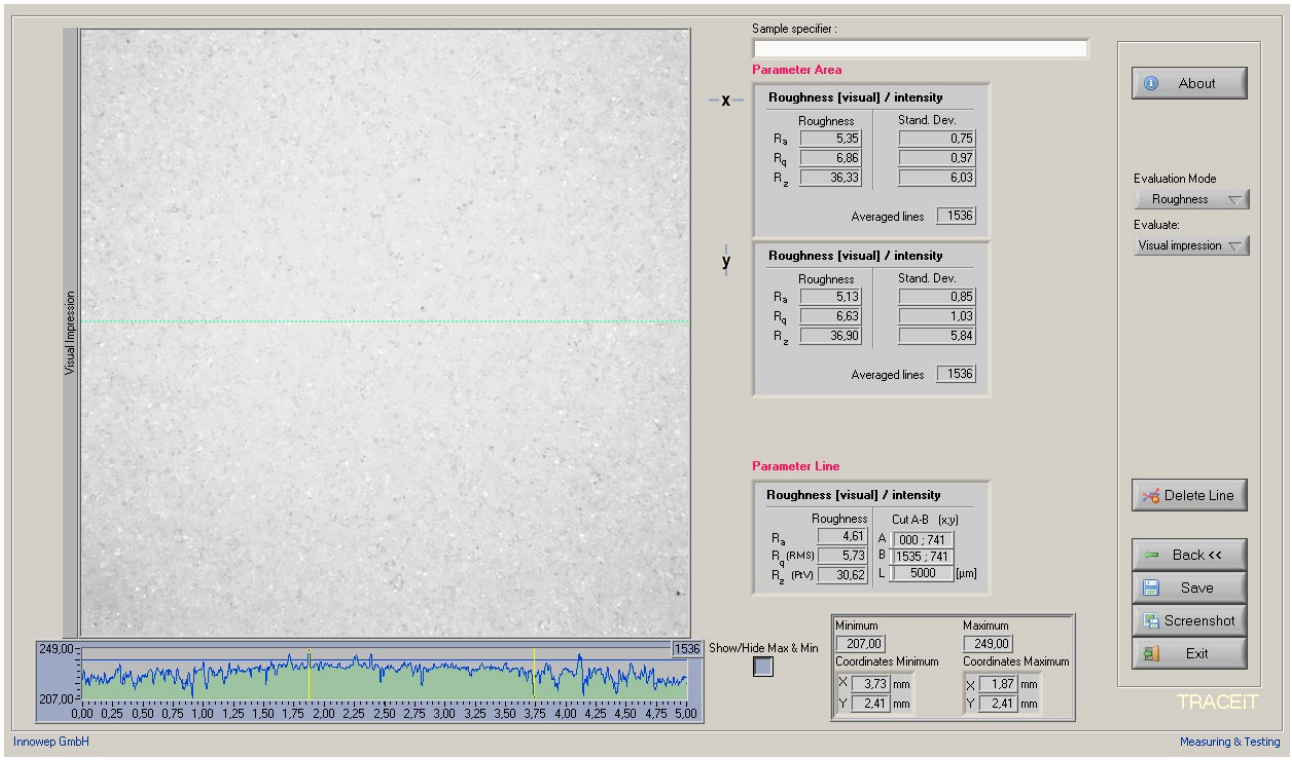
Total view



Results topography

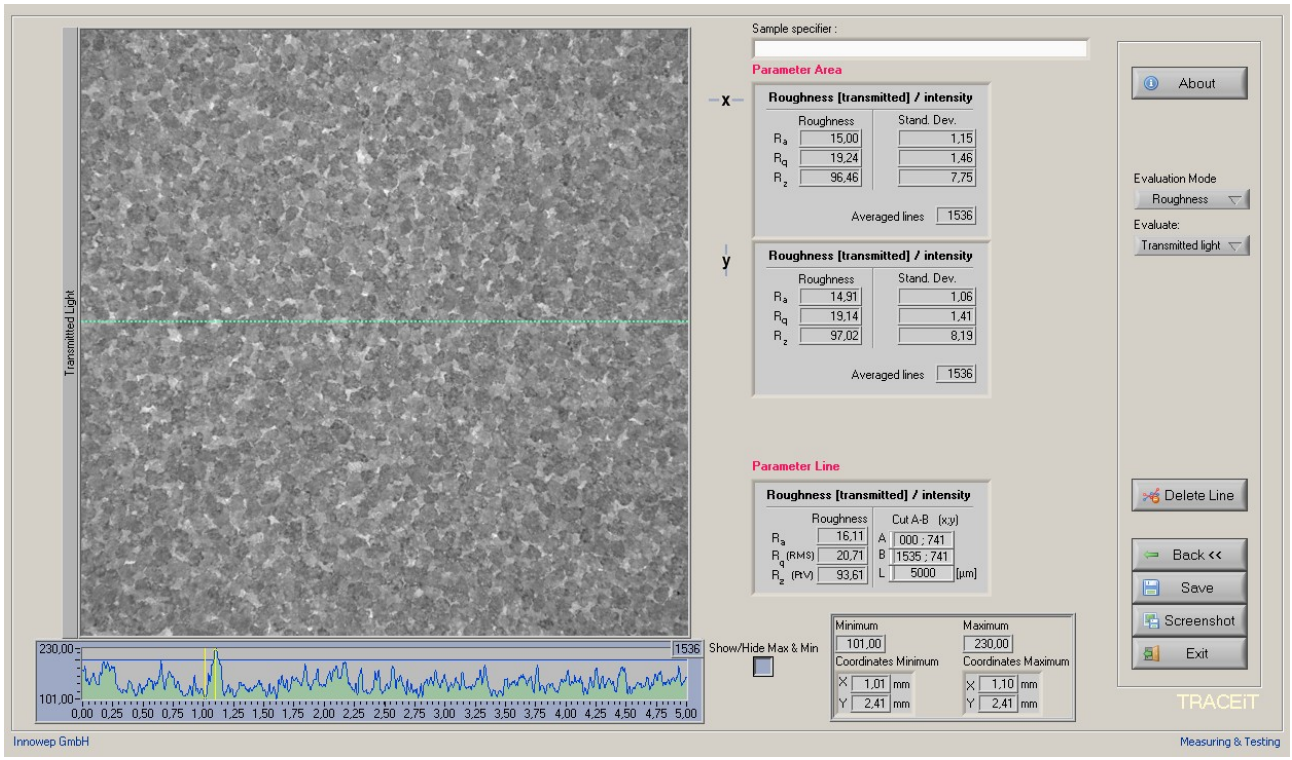


Results visual impression



The evaluation is done in the style of the topography but in gray tone units. Therefore the roughness parameters have no defined unit.

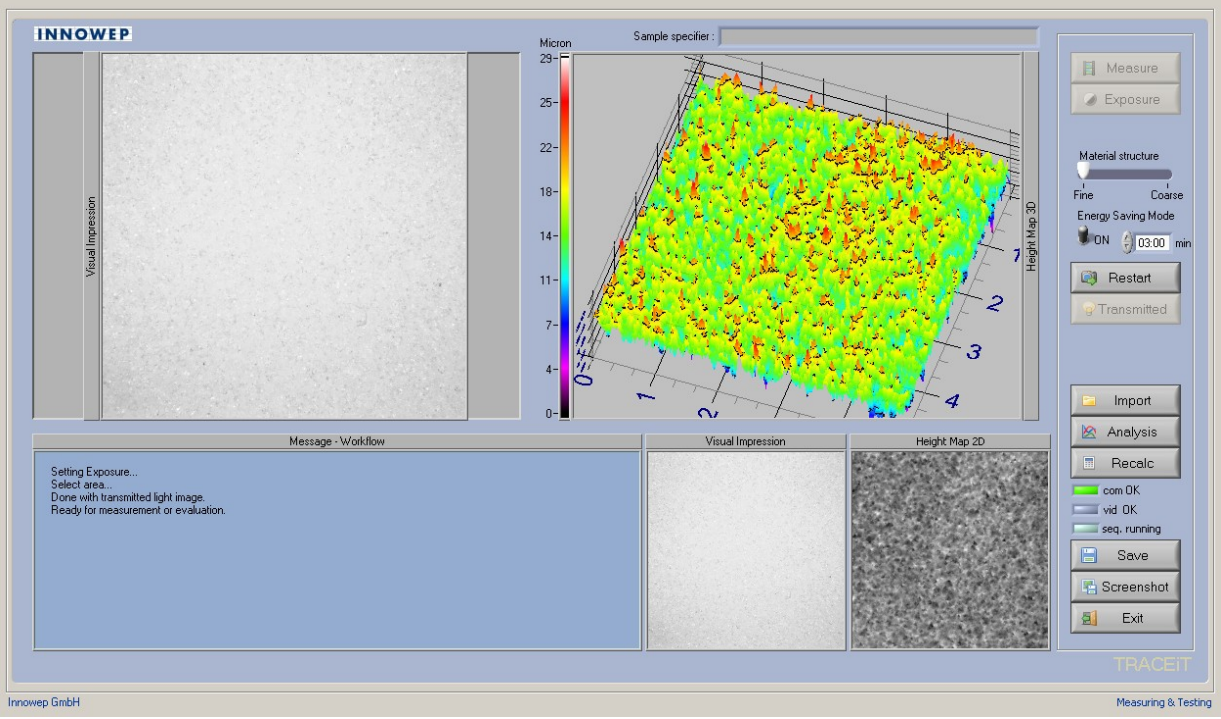
Results transmitted light mode



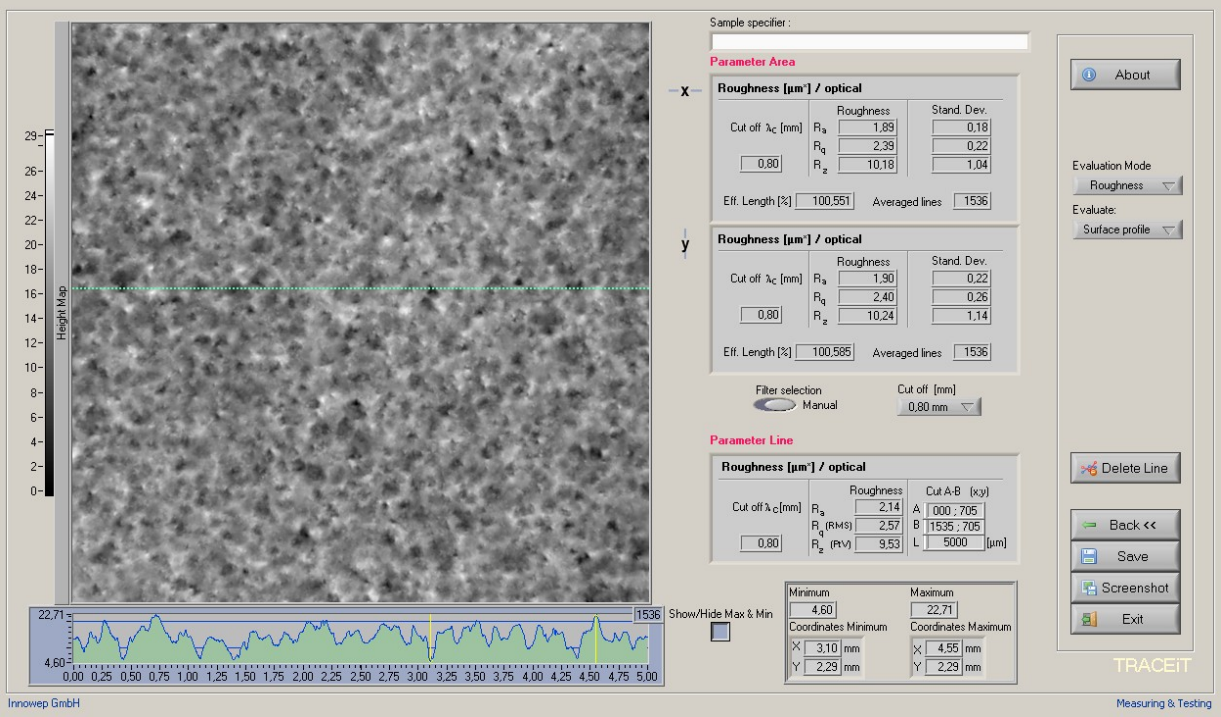
The evaluation is done in the style of the topography but in gray tone units. Therefore the roughness parameters have no defined unit.

4.3 Sample 3

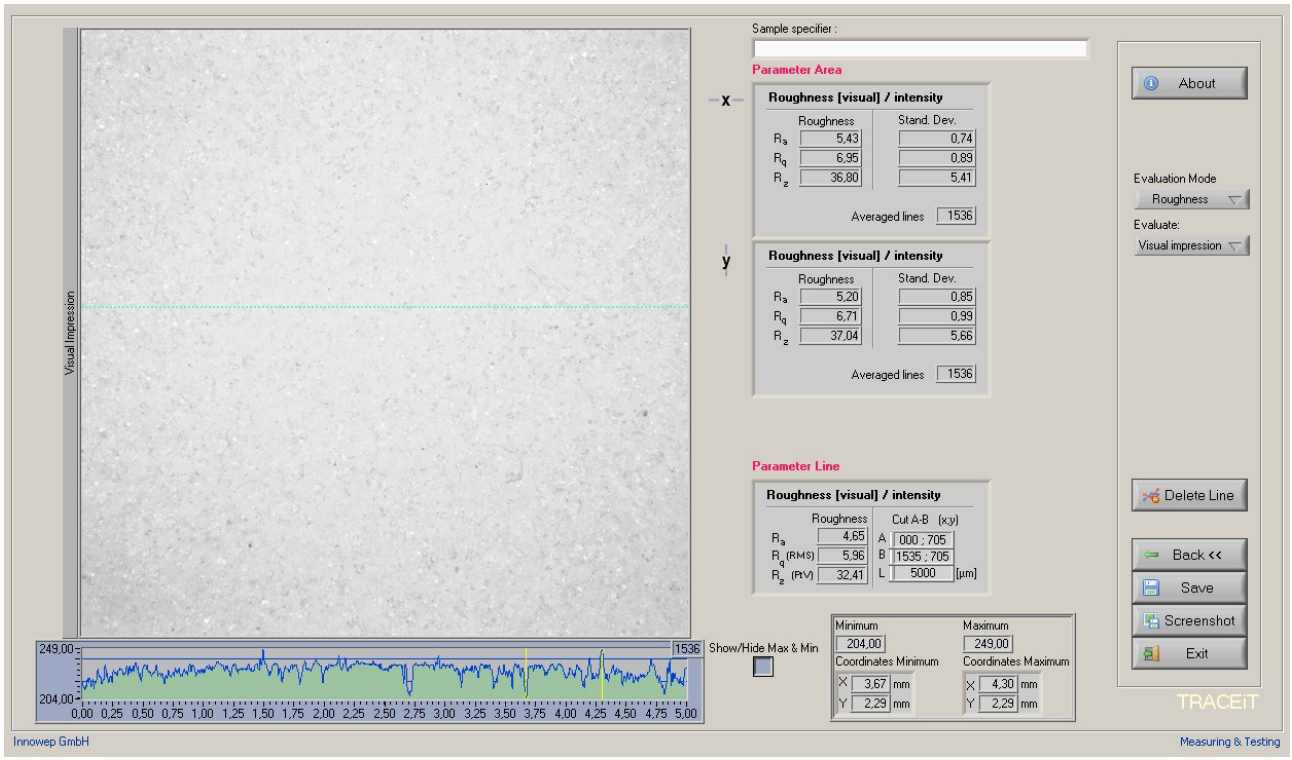
Total view



Results topography

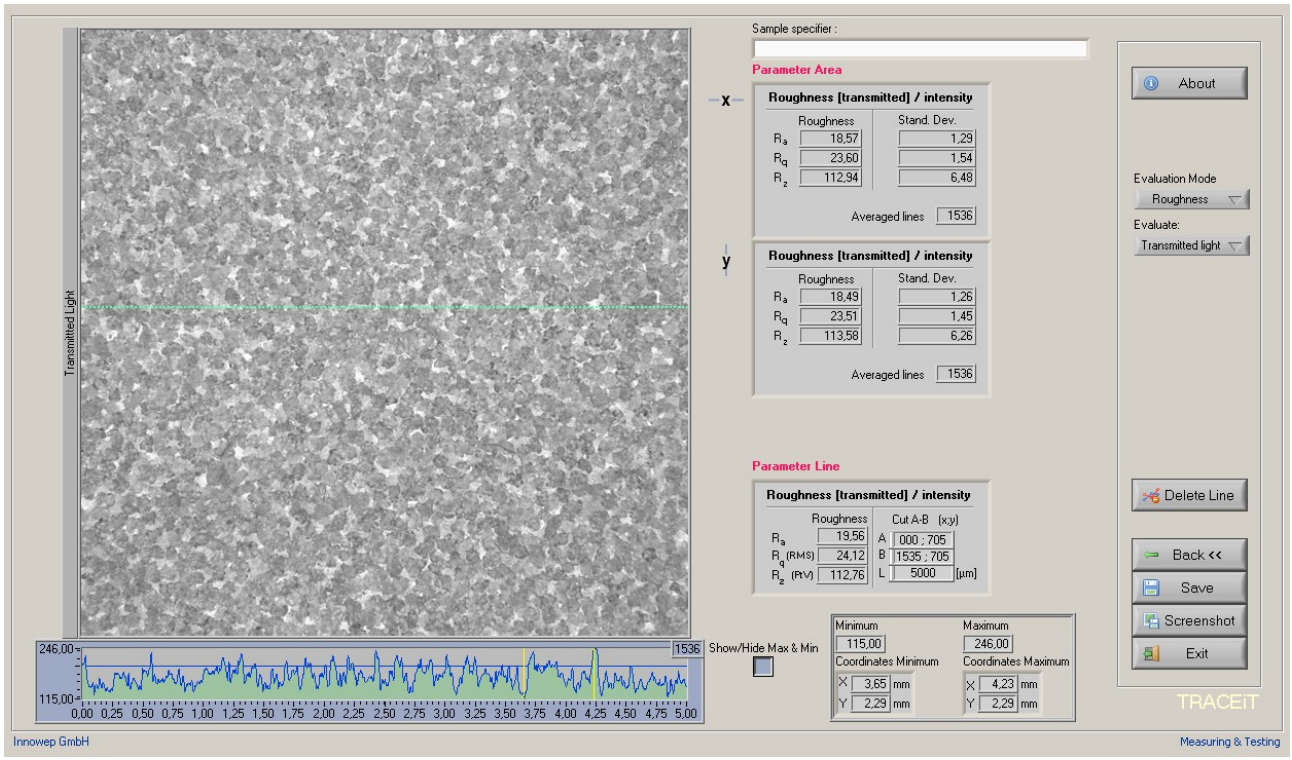


Results visual impression



The evaluation is done in the style of the topography but in gray tone units. Therefore the roughness parameters have no defined unit.

Results transmitted light mode



The evaluation is done in the style of the topography but in gray tone units. Therefore the roughness parameters have no defined unit.

4.4 Compilation of results

The evaluation of the topography, visual impression and transmitted light resulted the following roughness parameters that were calculated over 1500 rows in x and y direction each:

Topography

Sample	Direction	R_a [µm]	$\sigma(R_a)$ [µm]	R_q [µm]	$\sigma(R_q)$ [µm]	R_z [µm]	$\sigma(R_z)$ [µm]
1	x	1.93	0.20	2.44	0.24	10.29	0.97
	y	1.90	0.18	2.39	0.22	10.21	1.00
2	x	1.86	0.22	2.35	0.26	10.01	1.15
	y	1.87	0.18	2.36	0.23	10.07	1.07
3	x	1.89	0.18	2.39	0.22	10.18	1.04
	y	1.90	0.22	2.40	0.26	10.24	1.14

The topography of each sample shows almost no anisotropy. The roughness parameters in x and y direction are almost equal.

There are slight differences in the roughnesses of the three samples. They can be ranked (beginning with the flattest):

$$2 \lesssim 3 \lesssim 1$$

Visual impression

Sample	Direction	R_a [µm]	$\sigma(R_a)$ [µm]	R_q [µm]	$\sigma(R_q)$ [µm]	R_z [µm]	$\sigma(R_z)$ [µm]
1	x	5.37	0.76	6.87	0.91	36.70	5.27
	y	5.14	0.85	6.63	0.99	36.84	5.36
2	x	5.35	0.75	6.86	0.97	36.33	6.03
	y	5.13	0.85	6.63	1.03	36.90	5.84
3	x	5.43	0.74	6.95	0.89	36.80	5.41
	y	5.20	0.85	6.71	0.99	37.04	5.66

There are slight anisotropies between x and y direction on all three samples. There is no obvious reason for this.

The visual roughnesses of the three samples are almost equal to each other. They can be ranked (beginning with the flattest):

$$2 \approx 1 \lesssim 3$$

Transmitted light

Sample	Direction	R_a [µm]	$\sigma(R_a)$ [µm]	R_q [µm]	$\sigma(R_q)$ [µm]	R_z [µm]	$\sigma(R_z)$ [µm]
1	x	16.05	1.12	20.56	1.42	101.93	7.66
	y	15.96	1.23	20.43	1.53	102.12	8.08
2	x	15.00	1.15	19.24	1.46	96.46	7.75
	y	14.91	1.06	19.14	1.41	97.02	8.19
3	x	18.57	1.29	23.60	1.54	112.94	6.48
	y	18.49	1.26	23.51	1.45	113.58	6.26

There are slightest anisotropies between x and y direction on all three samples. This can result from the production process.

In the transmitted light mode large differences can be seen between the three samples. They can be ranked (beginning with the flattest):

$$2 < 1 \ll 3$$

This means that sample 2 has the densest, sample 3 the most porous material.

In the TRACEiT software there is a special module called “Particle mode”. With it height cuts can be applied not only to the topography but also to the visual impression image and the transmitted light image. To detect the porosity of the samples it was applied to the transmitted light images. With the “Histogram z-values” control unit the area of interest can be marked. Here the gray level values from 205 (light gray) to 255 (white) are marked which should be the part where the material is the most loosened. As a result the amount of area (absolute in mm² or as percentage of the measurement area of 25 mm²) is given.

Sample	Particle area [mm²]	Particle area [%]
1	0.27	1.10
2	0.12	0.48
3	2.14	8.56

This confirms the results of the transmitted light roughnesses. Sample 2 has the tightest, sample 3 the most loosened material.

5. Summary

One of the strengths of the TRACEiT® system is the direct comparison between visual impression and topographic roughness. The results are are documented reproducible by the system. Thus, they can be consulted for comparative measurements or damage evaluation and its documentation.

The three samples were characterized regarding their topography, visual impression and porosity. The samples have almost equal topographies and visual impressions but clear differences in their porosities. With the height cut module of the TRACEiT software the porosity could be examined in more detail.

There is the possibility to submit the measured data in electronic form for further evaluations. If you have further questions to the results or the TRACEiT® system do not hesitate to contact us.