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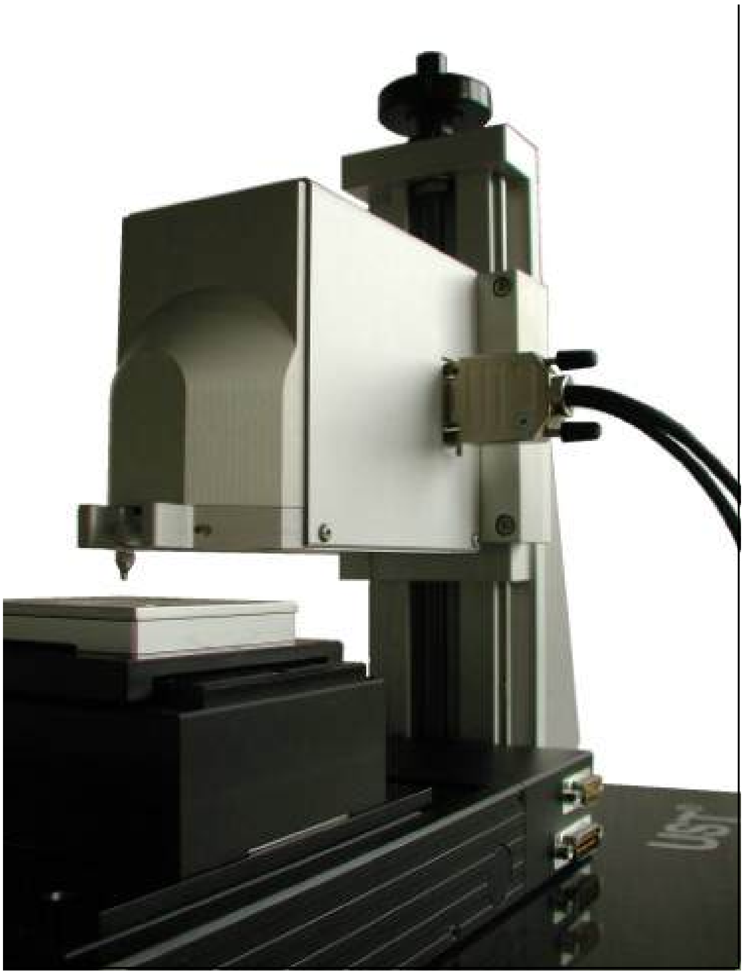
# Test Report UST® - Universal Surface Tester



Würzburg, 2012-04-17

Customer:

Samples: Contact Lenses

Report no.:

Test engineer: I

Report by:

Sign

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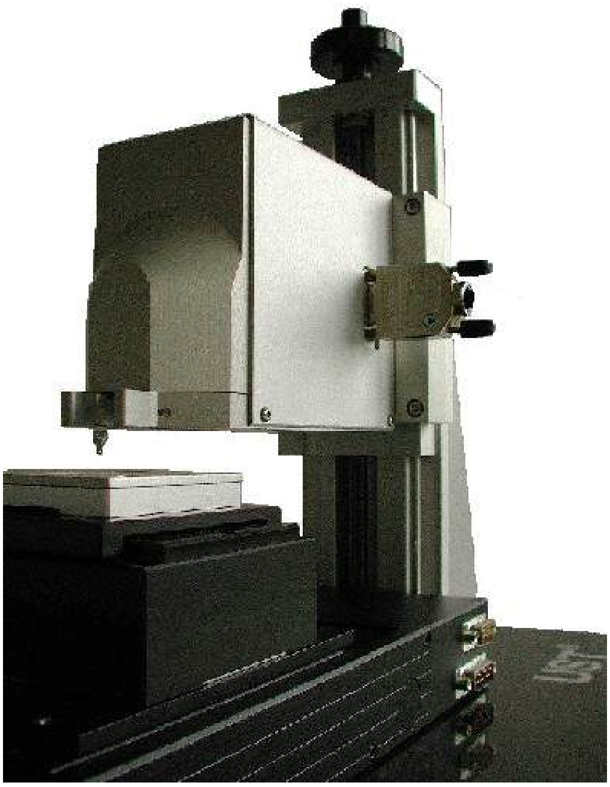
# 1. General description UST®

With the mechanical micro structure analysis (MISTAN®) procedure it is possible to determine mechanical, topographical and functional properties continuously on various surfaces.

The Universal Surface Tester UST® continuously determines the materials behavior and the corresponding deformation.

Therefore objective information can be obtained for the following material properties:

- Elasticity and plasticity
- Roughness and topography
- Total deformation
- Micro hardness
- Viscoelastic properties
- Scratch resistance
- Abrasion
- Softness/Haptics
- Compressibility
- Micro force measurement
- Material homogeneity



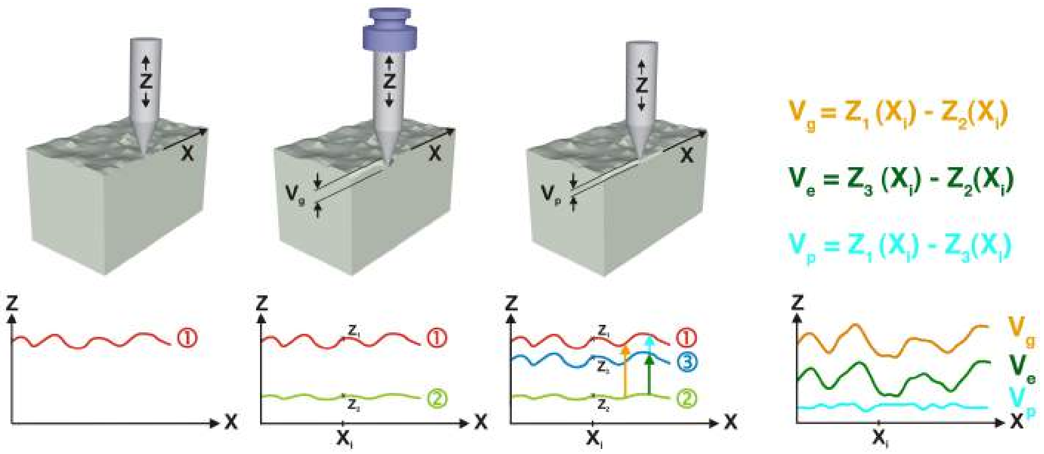
Universal Surface Tester UST®

# 2. Measuring principle

## 2.1 Deformation measurement (UST® standard measurement)

The MISTAN®-procedure enables variable load range scanning. During the tactile measurement a stylus is moved linear on the material surface for three times. The topography is recorded with a z-resolution of 60nm.

MISTAN® principle




First step (red)

Scanning along a definite path on the material's surface with a minimum load of 1 mN. As a result the vertical deflection of the stylus and therefore the surface texture is continuously determined (virgin profile).

Second step (green)

The same path is now scanned with the same stylus under a defined and constant load. A deformation of the surface occurs. This is called the total deformation $V_g$.

Third step (blue)

Third In this step the same path is scanned again with a minimum load. The elastic part of the total deformation is now recovered, it is called $V_e$. The permanent deformation $V_p$ is the part that does not recover.

Fourth step

The local deformation values are calculated based on the differences between the surface and deformation profiles (step 1, step 2 and step 3) and shown in the second graph window.

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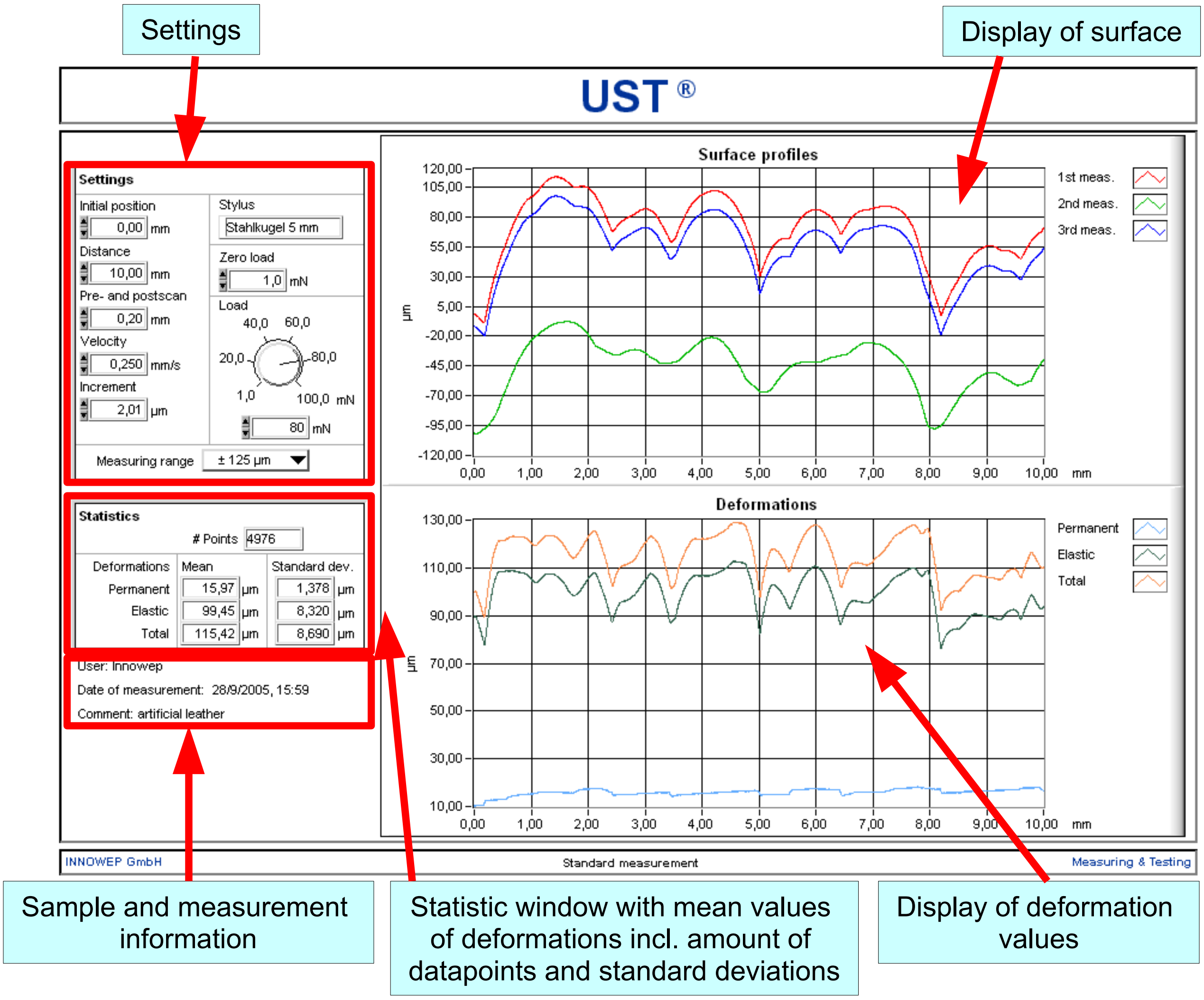
The measurement can be viewed online in the upper window. After it is finished the program calculates the deformation curves and displays them in the middle window.

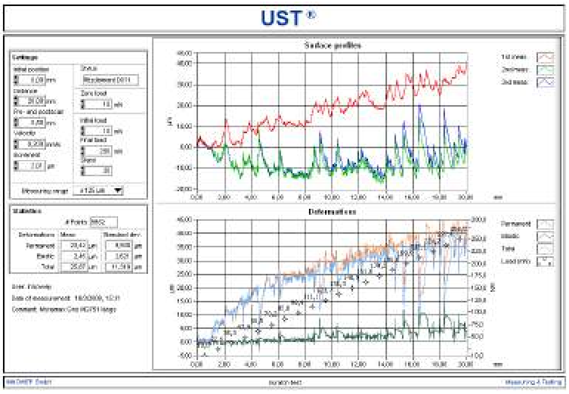
| | |
|---|---|
| Orange line | Total deformation |
| Green line | Elastic deformation |
| Light blue line | Permanent deformation |



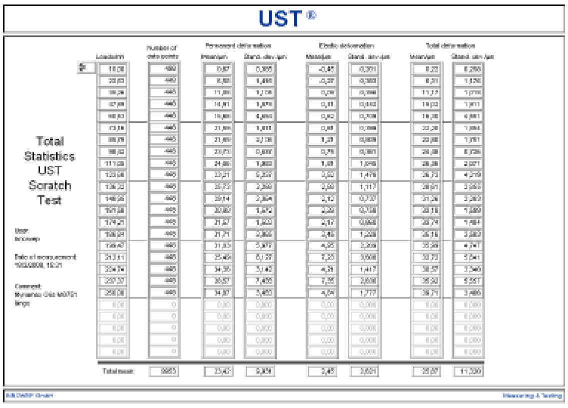

UST® software, 2D standard measurement

## 2.2 Scratch test

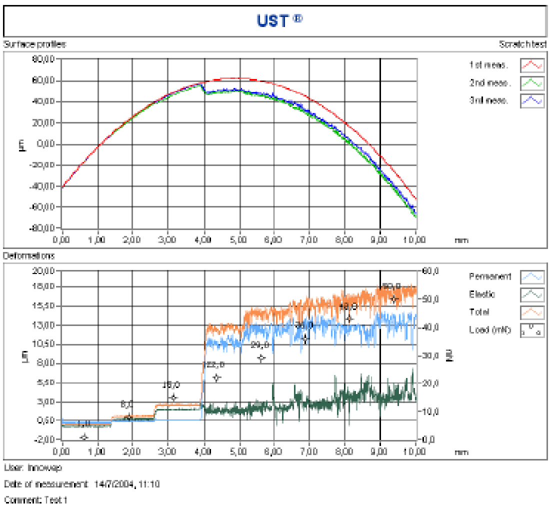
The scratch test module is based on the MISTAN® procedure. During the second step the load is increased stepwise to a final load. Depending on the UST® version there are start and final loads between 1 mN and 1000 mN possible. The number of load steps can be chosen from 1 to 100 steps.



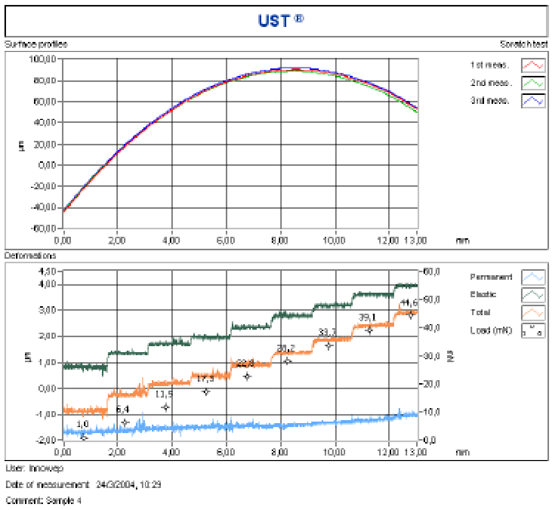

As a result the total as well as the permanent and elastic deformation values are given. Additionally, a statistic for each individual load step can be listed.




Formation of a scratch (loss of material)



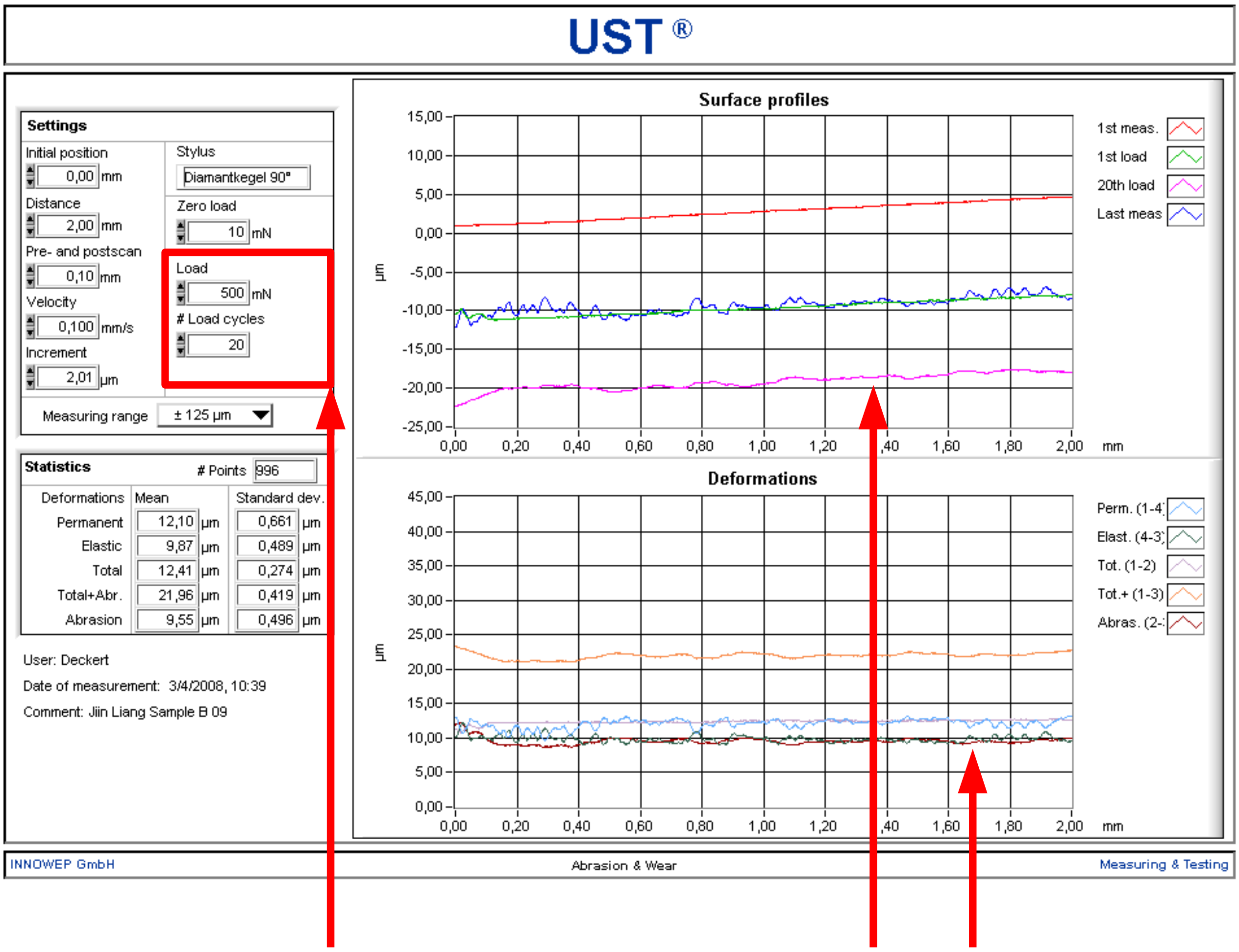

Formation of a groove (no loss of material)




Examples for typical damages during a scratch test

## 2.3 Abrasion

The abrasion module is based on the MISTAN® principle though the second step under load is repeated arbitrary times. So, besides the elastic and permanent deformations also the abrasion behavior under defined parameters can be investigated.



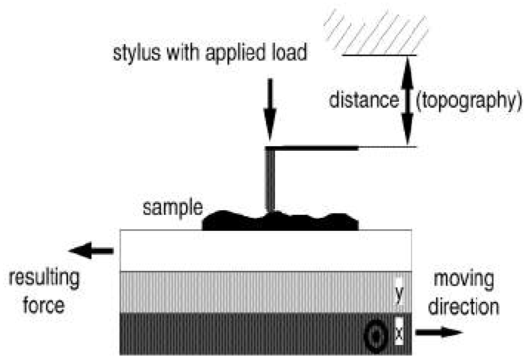

A change of the mistan-procedure allows a repetition of the second load step (constant load) as often as wanted. The so obtained identification of deformations and amount of abraded material yields a clearly understandable locally differentiated statement for the wear resistance. All areas of interest can be zoomed out for a deeper investigation.

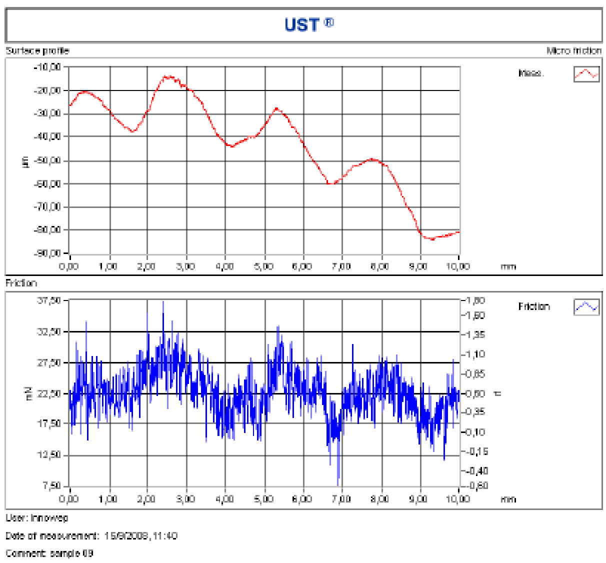
Additional to the three surface and deformations profiles within the standard measurement, the UST® records the last load step of the abrasion test. The difference between the first and the last load cycle gives the local value of abrasion.

## 2.4 Micro friction

With the additional module "Micro friction" the analysis possibilities of the Universal Surface Tester are enhanced by the measured value of friction forces. It can be used as a standalone module or be combined with the standard measurement or scratch test. The measurement table (picture on the right) is mounted on the processing table, which is applied by the friction force. The counter-body on the sample, is detected by a highly sensitive piezo sensor, which is integrated into the measuring table. The measurement module can be used for haptical as well as microtribological investigations on flat and structured surfaces. In contrast to conventional force gauges the sensor has an extremely high frequency and stiffness and is therefore able to measure highly dynamic, without proper inertia, and with an extremely high local resolution. The module enables measurements in a large effective range with high force resolution in the sub-nm regime.


In the upper window of the micro friction software module the actual profile of the surface structure is displayed. In the lower window the friction forces during measurement are displayed. When the measurement is finished the averaged friction forces and friction coefficient μ are displayed in the statistics window.



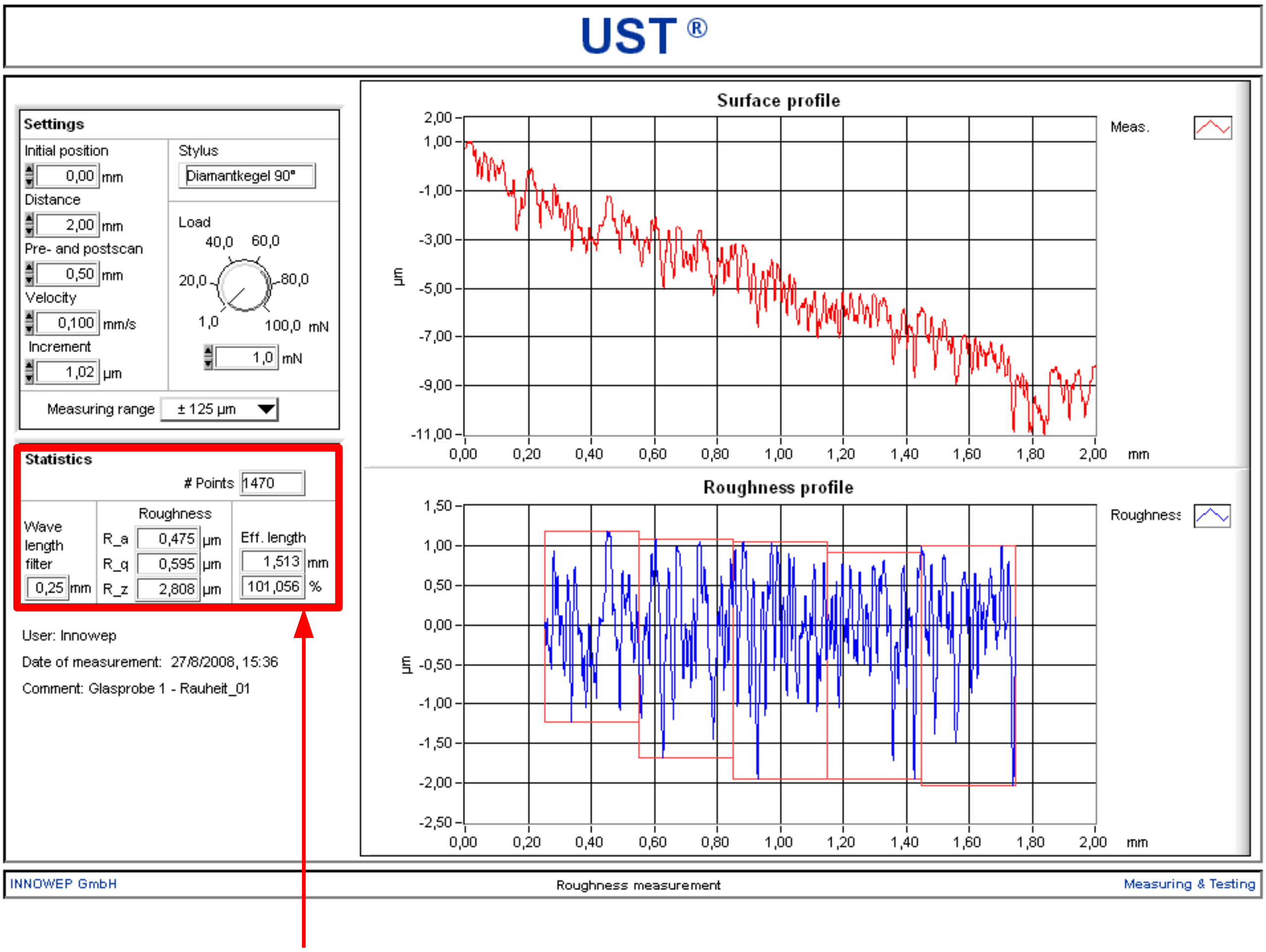

⇦ Surface structure

⇦ locally resolved, corresponding dynamic micro force signal

## 2.5 Roughness according to DIN EN ISO 4287

With the roughness module the roughness of a surface is evaluated according to DIN EN ISO 4287 bestimmt. The surface is scanned with a freely definable load. Afterwards the roughness values $R_a$, $R_q$ and $R_z$ are calculated automatically. With this module the roughness values can also be evaluated from previous standard, 3D standard, 3D topography, scratch or abrasion measurements.

In the upper window the surface profile is shown, in the lower window the roughness after subtraction of a linear offset and calculation with a selectable wavelength filter is displayed graphically. The statistic analysis is displayed in the lower left part of the measurement window.

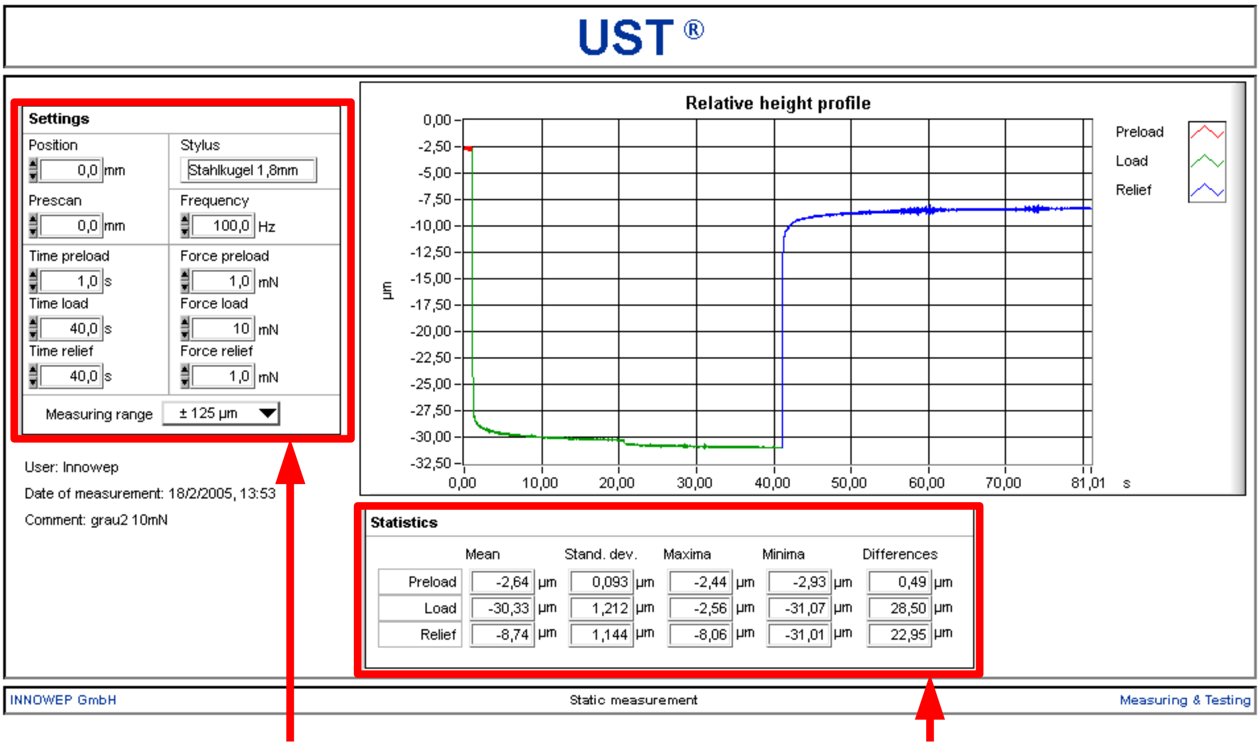



The wavelength filter is chosen automatically according to the international norm. To get additional information or to calculate the roughness of small surfaces the wavelength filter can also be chosen by hand.

Additionally to the roughness values $R_a$, $R_q$ and $R_z$ the system evaluates the effective length in mm and as percentage of the total measuring distance.

## 2.6 Viscoelasticity / Static measurement

For assessment of the viscoelastic material properties, a selective analysis is taken out and presented as a function of time. During the load duration, a characteristic material behaviour can be observed: the material resistance under load (green line). During the relief stage a period of complete resetting of the elastically deformed part can be seen (blue line). The shape of the graph enables to understand the viscoelastic character of the material.




The graph is a function of time. Time and force of preload, load and relief can be set by the user.

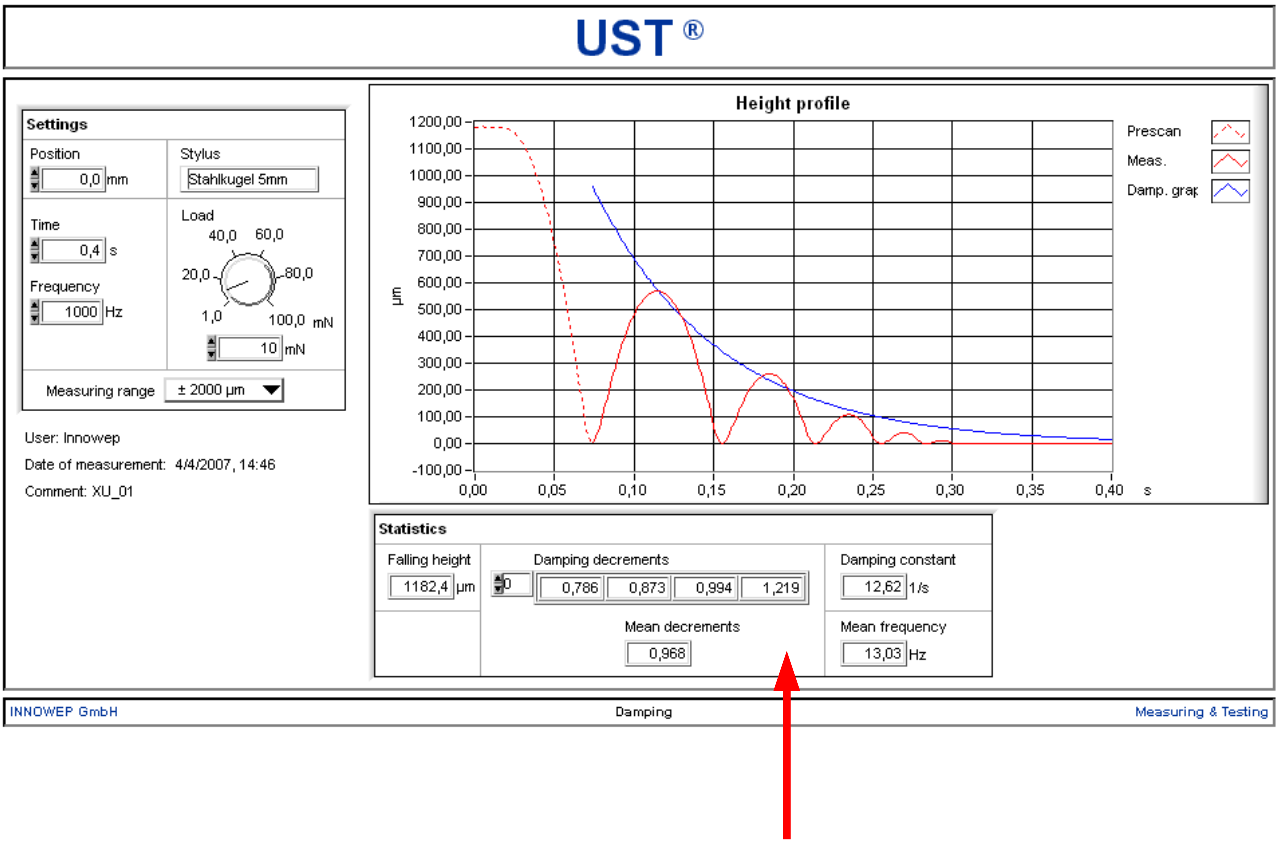
The differences in displacement under preload, load and relief are stated in the statistics box.

Based on this UST® module, many hardness and viscoelasticity measurements can be done according to international standards. Depending on the applied standard, a special tip geometry may be required.

## 2.7 Damping

The elastic properties of soft materials can be examined especially well with the damping module. The stylus is dropped from a defined height with a defined load onto the sample surface. The height signal is recorded during fall and bouncing.

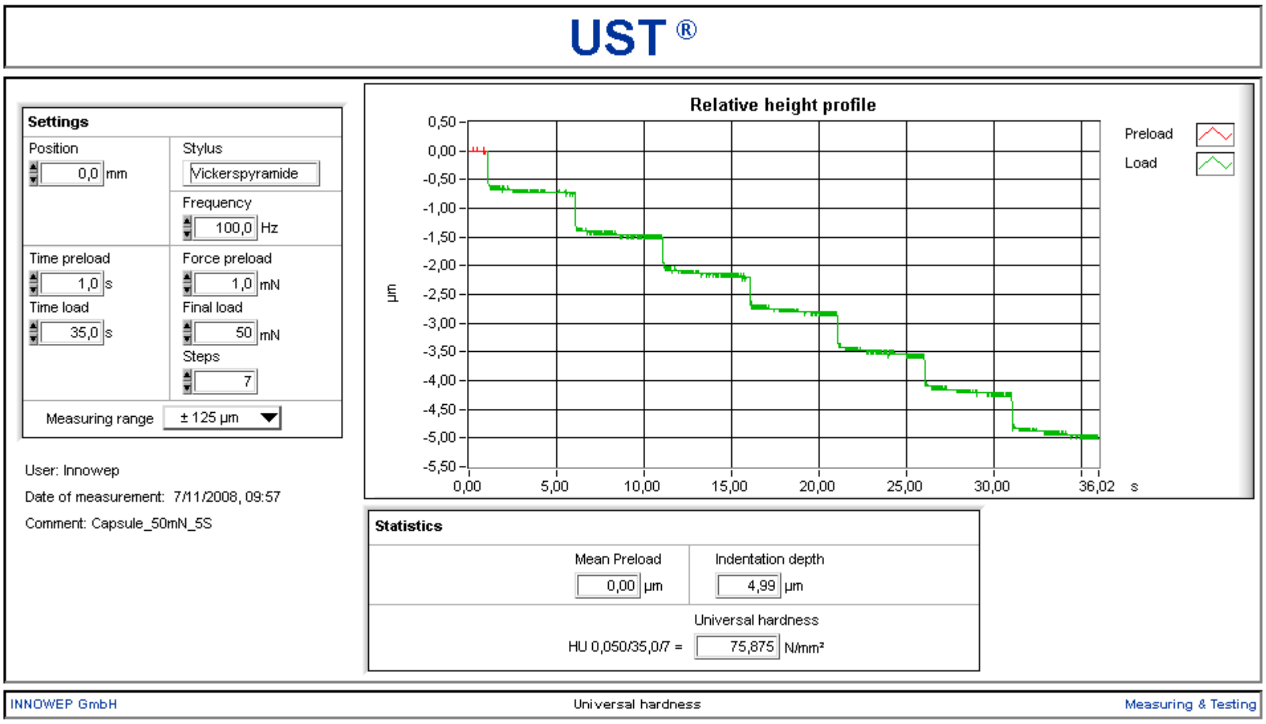
Depending on material, stylus and load the tip will bounce off the surface for a couple of times. The result is a damped oscillation, displayed in the graph window and evaluated for damping constant and mean frequency.




In the statistics windows below the graph window the falling height of the stylus, the first four damping decrements, their mean value, the damping constant and the mean frequency of oscillation are displayed.

## 2.8 Universal hardness

The measurement mode “Universal hardness” enables the evaluation of hardness values according to DIN EN ISO 14577-1. It consists of two steps: A predefined load will be applied to the stylus for a given time (preload). After that the load on the stylus will be increased stepwise over a predefined period. During the whole measuring time the signal of the stylus will be recorded. Finally the universal hardness is calculated from the total deformation that has been measured.




The universal hardness is given e.g. as HU 0.050/35.0/7 (see picture above) which means

HU: universal hardness measurement

0.050: final load in N (here 50 mN)

35.0: time of load in s (here 35 s)

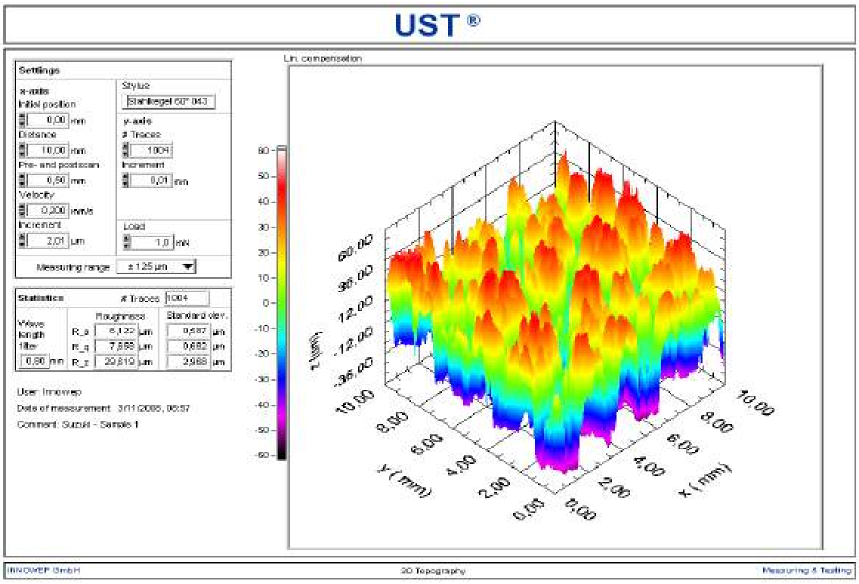
7: number of steps (here 7)

The unit of the universal hardness is [N/mm²].

## 2.9 3D topography

For the 3D topography measurement the height profile is scanned over several parallel lines. The distance in y-direction between these lines is freely adjustable. During measurement the height profile of each line is shown. Afterwards, the 3D topography is shown but can be switched to a 2D view of each line. In the lower left corner the statistics of the roughness values can be found.

In a special height cut mode it is possible to evaluate particles and porosity.



# 3. Samples

The samples measured in this study were five different types of contact lenses:

- AAA (coated)
- AAA (uncoated)
- CCC
- DDD (uncoated)
- DDD (coated)

All measurements were performed in distilled water.

# 4. Results

## 4.1 Micro friction

The measurement with the module "Micro friction" was performed with the following parameters:

| Module | Roughness |
|---|---|
| Stylus | Ruby ball 1 mm |
| Load [mN] | 5 |
| Distance [mm] | 4 |
| Pre- and post scan [mm] | 0.1 |
| Velocity [mm/s] | 0.1 |
| Increment [µm] | 1.98 |

The measurement gave the following results, averaged over 3926 single points:

| Sample | Friction [mN] | fric. coeff. | Force Range [mN] |
|---|---|---|---|
| AAA (coated) | 0,68 ± 0,742 | 0,14 ± 0,149 | 5,12 |
| AAA (uncoated) | 1,59 ± 0,758 | 0,32 ± 0,152 | 7,50 |
| CCC | 1,28 ± 0,785 | 0,26 ± 0,157 | 5,53 |
| DDD (uncoated) | 4,73 ± 1,441 | 0,95 ± 0,288 | 9,52 |
| DDD (coated) | 3,67 ± 1,069 | 0,74 ± 0,214 | 9,67 |

The measurements show significant differences between the different contact lenses. Both silicone lenses show higher friction forces than all other lenses. And both at AAA and DDD the coating leads to lower friction values.

## 4.2 3D topography

The measurement with the module "3D topography" was performed with the following parameters:

| Module | 3D topography |
|---|---|
| Stylus | Diamond cone 90° |
| Load [mN] | 1 |
| Distance x direction [mm] | 1.5 |
| Distance y direction [mm] | 1.5 |
| Pre- and post scan [mm] | 0.5 |
| Velocity [mm/s] | 0.2 |
| Increment x direction [µm] | 2.01 |
| Increment y direction [mm] | 0.05 |

From the topographies, the roughness values $R_a$, $R_q$ and $R_z$ are calculated over 76 line scans:

| Sample | Ra [µm] | Rq [µm] | Rz [µm] |
|---|---|---|---|
| AAA (coated) | 0,421 ± 0,113 | 0,549 ± 0,173 | 2,595 ± 1,082 |
| AAA (uncoated) | 0,268 ± 0,082 | 0,381 ± 0,216 | 1,887 ± 1,149 |

# 5. Summary

One of the advantages of the UST® is the comparative measurement and direct in-situ analysis. Measuring different samples, the properties, advantages and disadvantages of the material structure can be clearly determined in situ and with high local resolution.

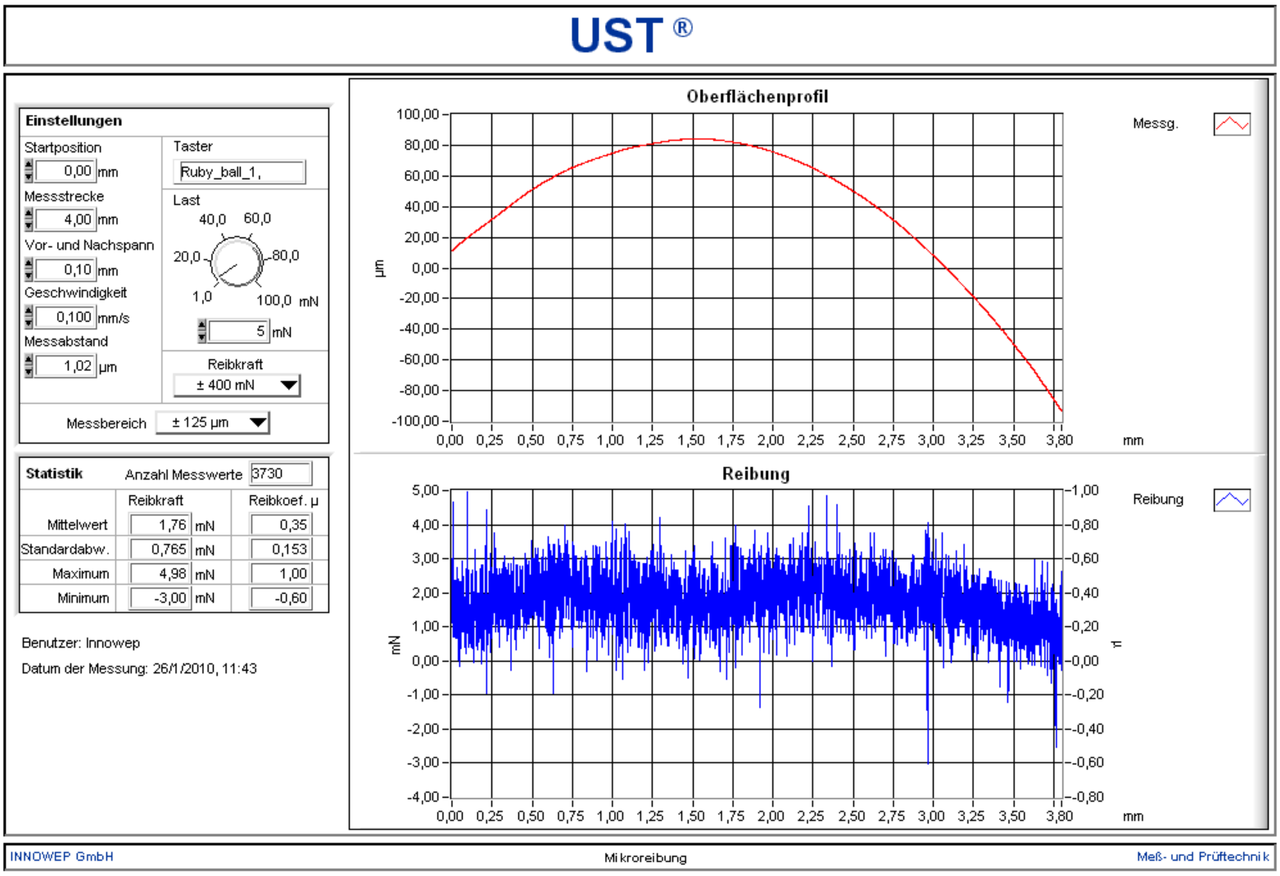
The measured samples showed significant differences with respect to their friction behavior.

For questions concerning the results, the UST® apparatus or further investigations you can ask us at any time.

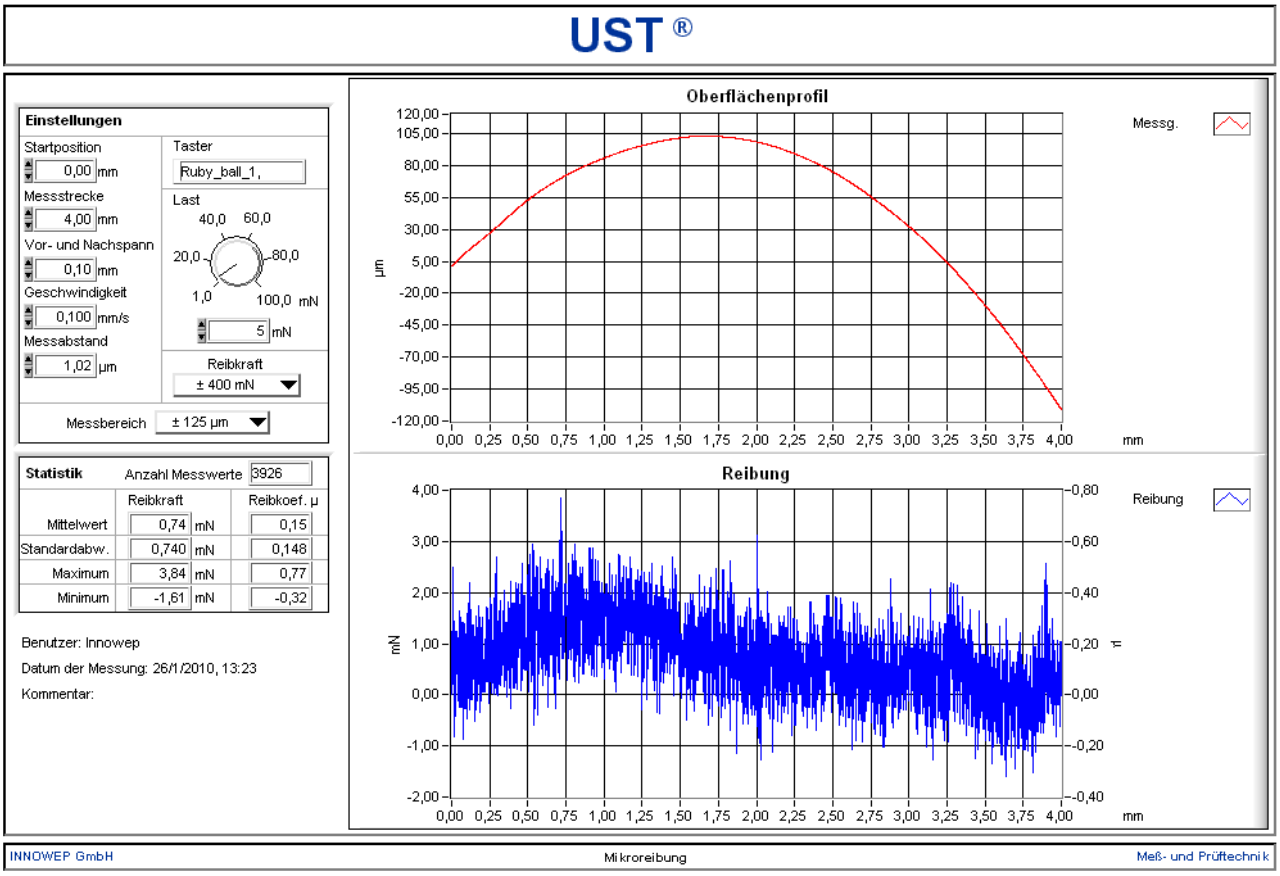
# 6. Appendix

## 6.1 Measurement window “micro friction”

AAA (uncoated)



## AAA (coated)


UST ®
Einstellungen
Startposition 0,00 mm
Messstrecke 4,00 mm
Vor- und Nachspann 0,10 mm
Geschwindigkeit 0,100 mm/s
Messabstand 1,02 µm
Taster Ruby_ball_1,
Last
5 mN
Reibkraft ± 400 mN
Messbereich ± 125 µm
Statistik
Anzahl Messwerte 3926
Reibkraft Reibkoef. µ
Mittelwert 0,74 mN 0,15
Standardabw. 0,740 mN 0,148
Maximum 3,84 mN 0,77
Minimum -1,61 mN -0,32
Benutzer: Innowep
Datum der Messung: 26/1/2010, 13:23
Kommentar:
Oberflächenprofil
Messg.
µm
mm
Reibung
mN
µ
INNOWEP GmbH
Mikroreibung
Meß- und Prüftechnik

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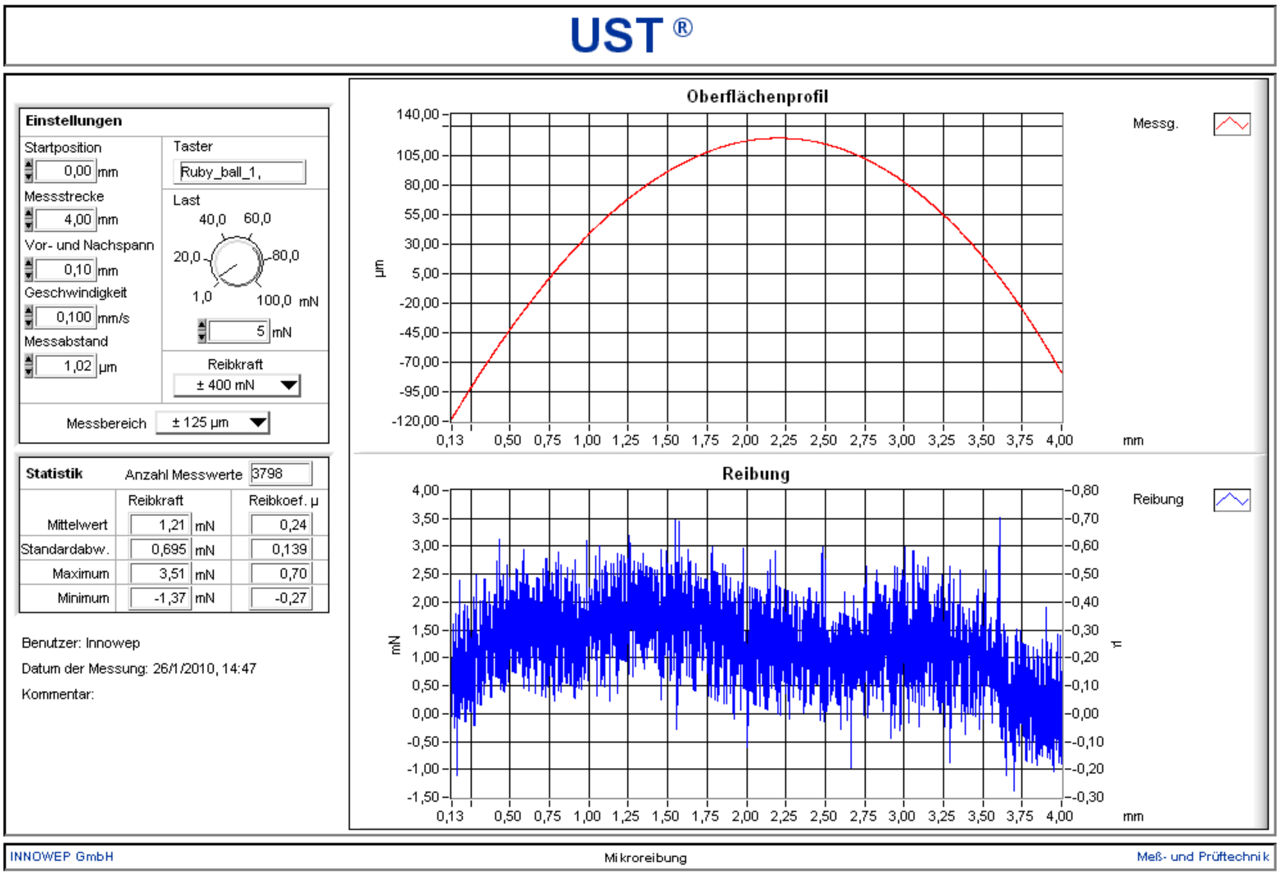
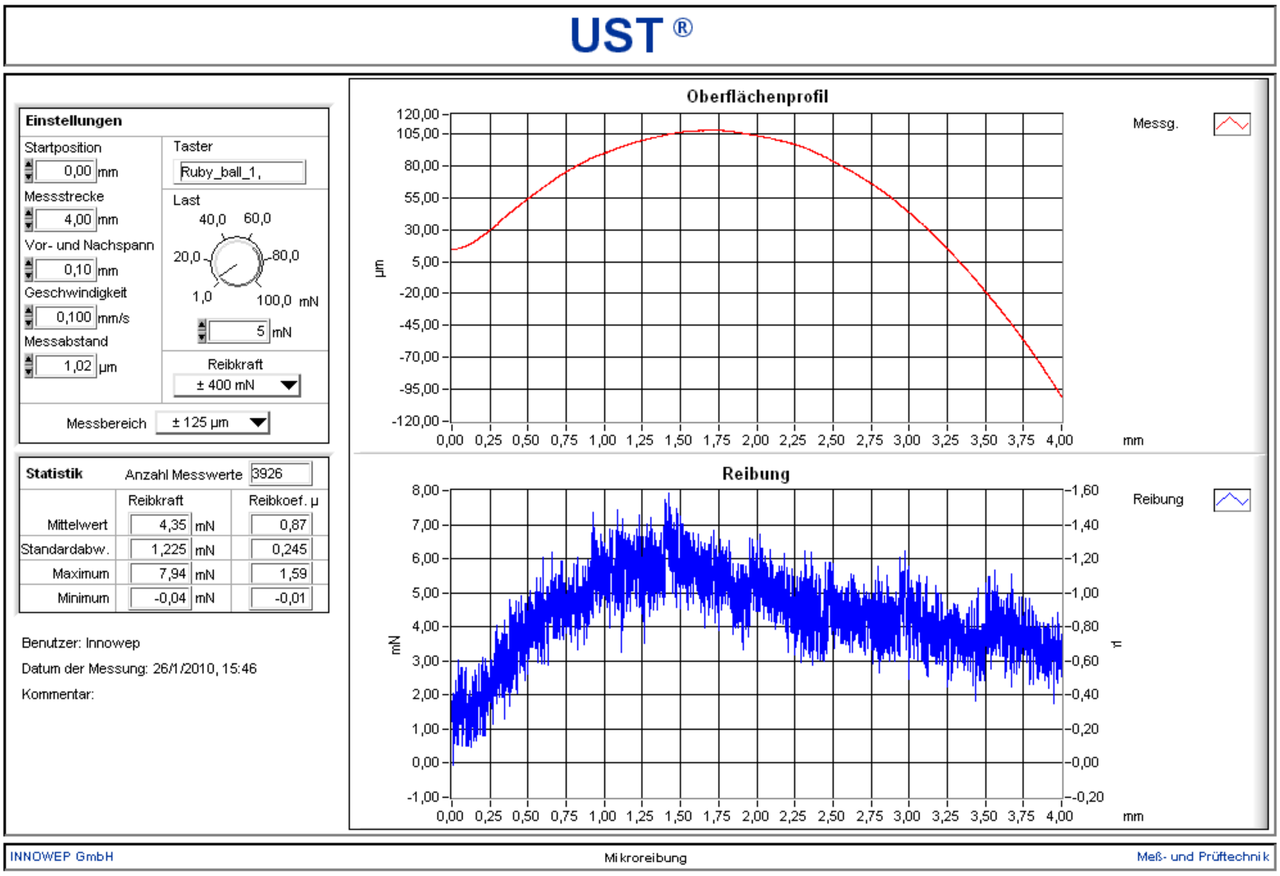
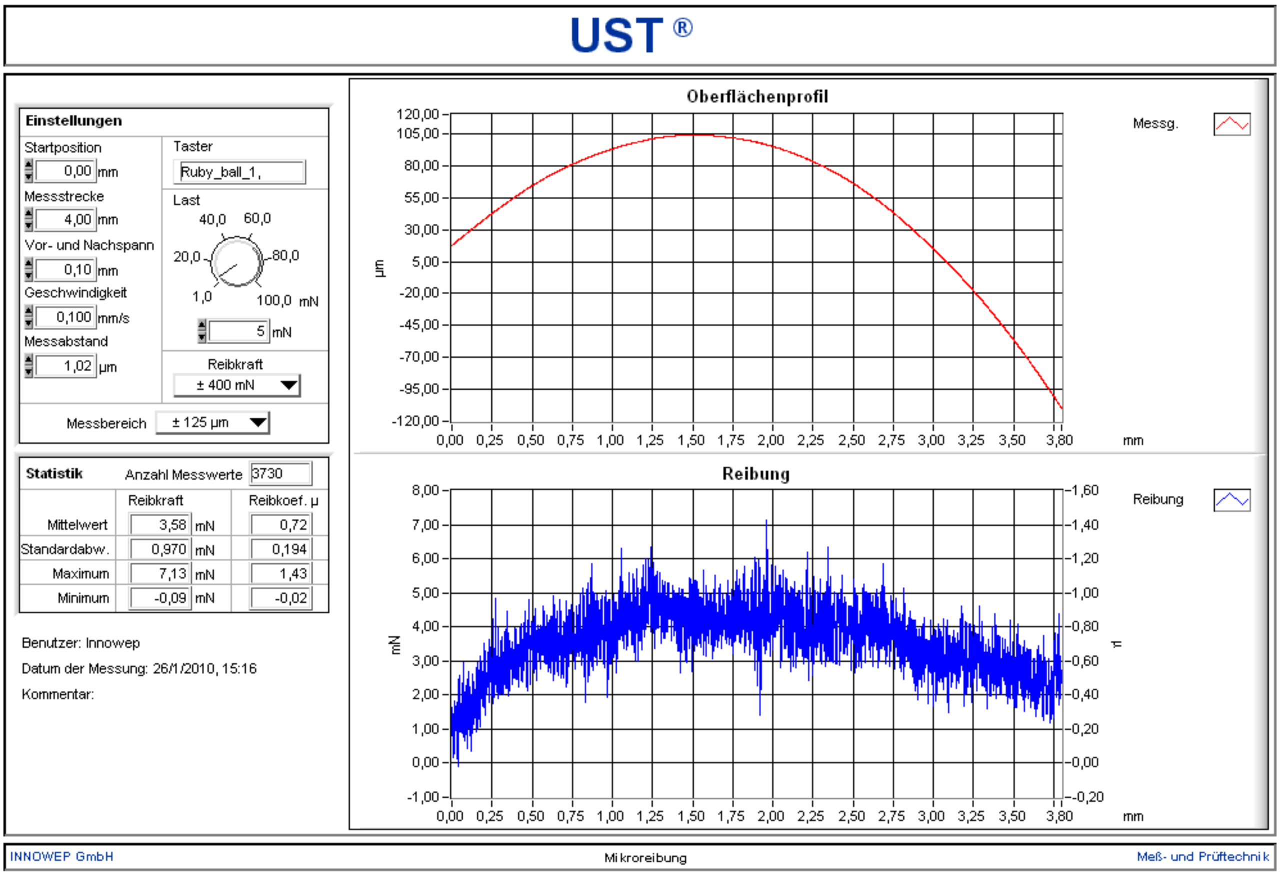
CCC



## DDD (uncoated)



DDD (coated)


UST ®
Einstellungen
Startposition 0,00 mm
Messstrecke 4,00 mm
Vor- und Nachspann 0,10 mm
Geschwindigkeit 0,100 mm/s
Messabstand 1,02 µm
Taster Ruby_ball_1,
Last 5 mN
Reibkraft ± 400 mN
Messbereich ± 125 µm
Statistik
Anzahl Messwerte 3730
Reibkraft / Reibkoef. µ
Mittelwert 3,58 mN 0,72
Standardabw. 0,970 mN 0,194
Maximum 7,13 mN 1,43
Minimum -0,09 mN -0,02
Benutzer: Innowep
Datum der Messung: 26/1/2010, 15:16
Kommentar:
Oberflächenprofil
Messg.
µm
mm
Reibung
mN
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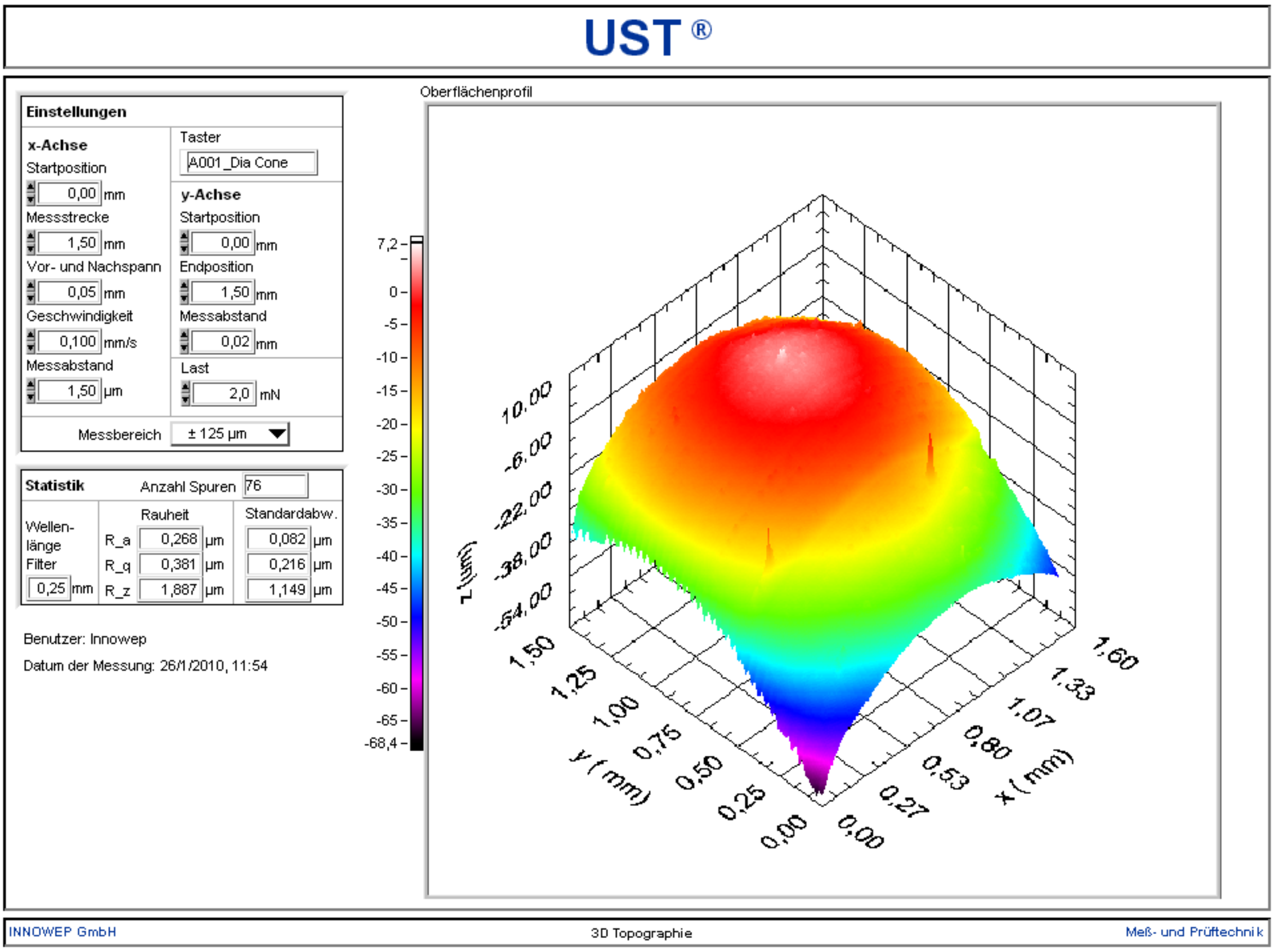
INNOWEP GmbH
Mikroreibung
Meß- und Prüftechnik

## 6.2 Measurement window “3D topography” (examples)

AAA (uncoated)



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## AAA (coated)