SINGLE LINE SUBTITLE WITH A MAXIMUM OF APPROX. 90 CHARACTERS

Advanced materials study by optical profiler with high magnification objectives

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Agenda

1 Bruker optical profiler introduction

2 High magnification objective

3 What are the top 8 applications by Bruker WLI in publication?

4 Advanced materials study by 3D OP

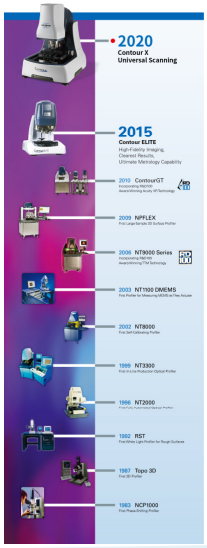
5 Summary

01

Bruker optical profiler introduction

Product Line: 40+ years innovation, Comprehesive, Industrial proven

The Most Versatile Metrology Solution by WLI



ContourX-100

ContourX-200

ContourX-500

Contour GT-X

NPFLEX-LA

NPFLEX

Contour SP

Insight WLI

Technology: Key Patents of Bruker's WLI, Developing and Innovation
The most advanced innovations over 40 years, focusing on WLI

Instrument hardware and algorithms

7654685
Dual Light

5446547
1cm close loop

5813809
Thread

7212356,
7375821
TTM

5978086
Anti-thermal

6266183
Anti-Crash

7605925
HDVSI
5555471
Thin Film
5471303,
6493093
VXI

5717782
Data Restore
6459489
SureVision

5987189,
5991461,
6185315
Stitch

Application

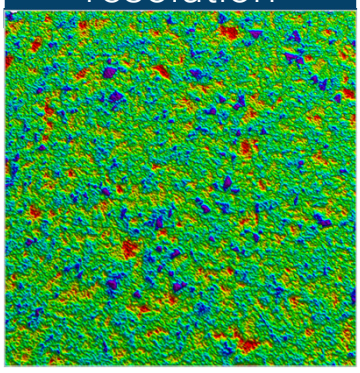
9664509
Signal sectioning for profiling printed-circuit-board vias with vertical scanning interferometry

7808652
Interferometric measurement of DLC layer on magnetic head

8643847
Interferometric technique for measuring patterned sapphire substrates

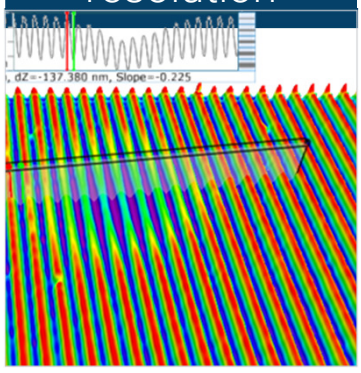
Best WLI Metrology solution on market
Resolution and slope

Sub-nm vertical resolution



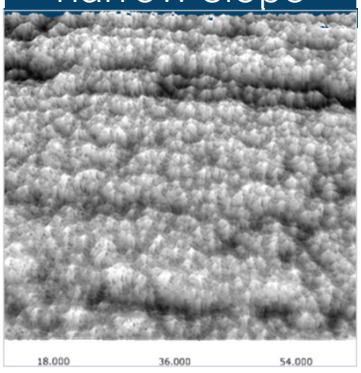
0.16nm vertical details on SiC mirror

Sub-µm lateral resolution



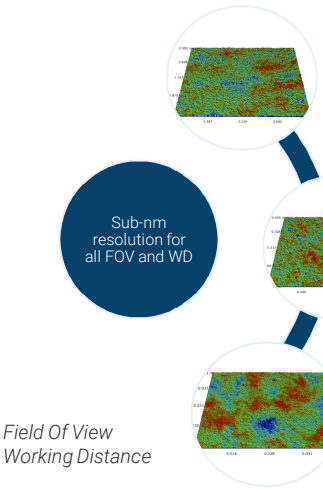
Defect on 1000 lines/mm diffractive polymer

Steady & narrow slope



Si etched pyramids with 45°slope

Vertical resolution



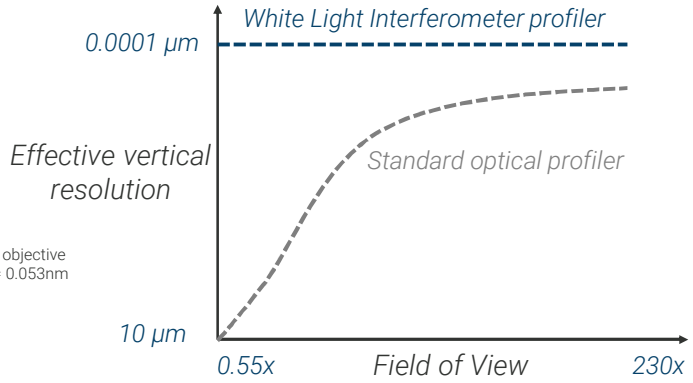
2.5x objective
Sa = 0.058nm

Sub-nm resolution for all FOV and WD

20x objective
Sa = 0.053nm

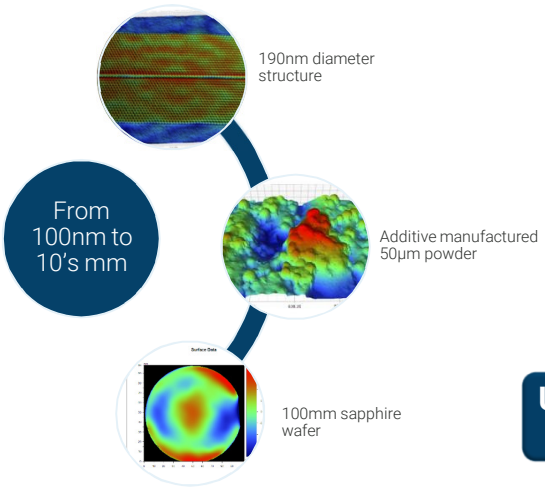
115x objective
Sa = 0.057nm

Field Of View
Working Distance



Best vertical metrology

Lateral resolution



190nm diameter structure

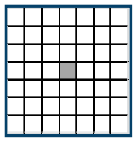
From 100nm to 10's mm

Additive manufactured 50µm powder

100mm sapphire wafer

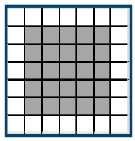
- Deterministic calculation for focus

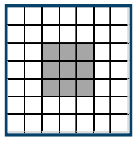
White Light Interferometry



Direct height extraction for each pixel results in best lateral resolution

Digital Microscope Focus Variation

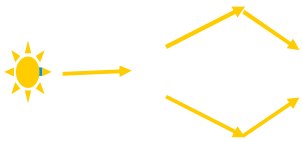




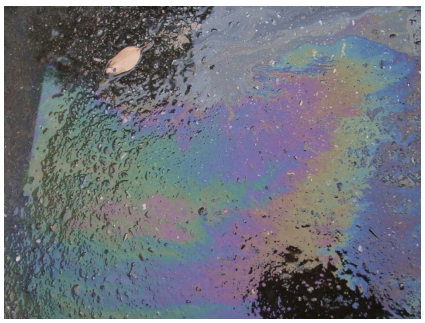
Multiple pixel averaged out for height extraction, lowering lateral resolution

Ultimate lateral resolution

Interferometry, Interferometer: principle

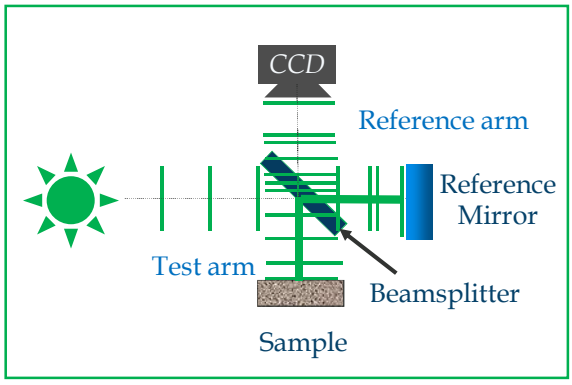


interference



Interferometer is an optical device that divides a beam of light exiting a single source (like a laser) into two beams and then recombines them to create an interference pattern. The combined pattern can be analyzed to determine the difference in paths the two beams traveled.

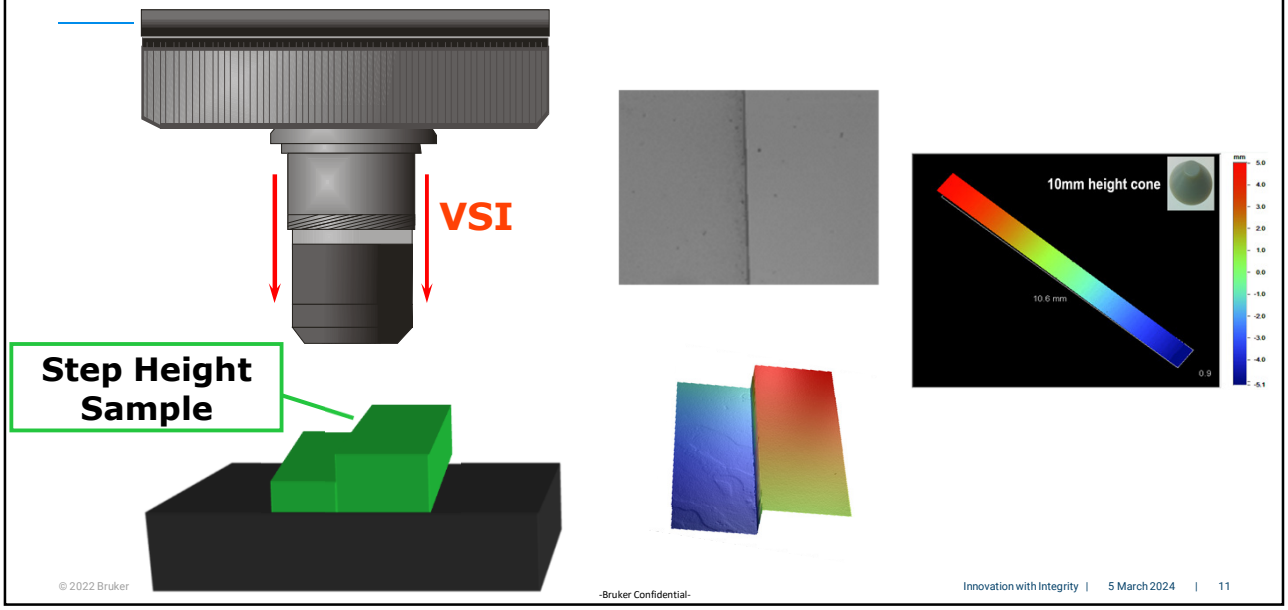
Typical interferometer: principle



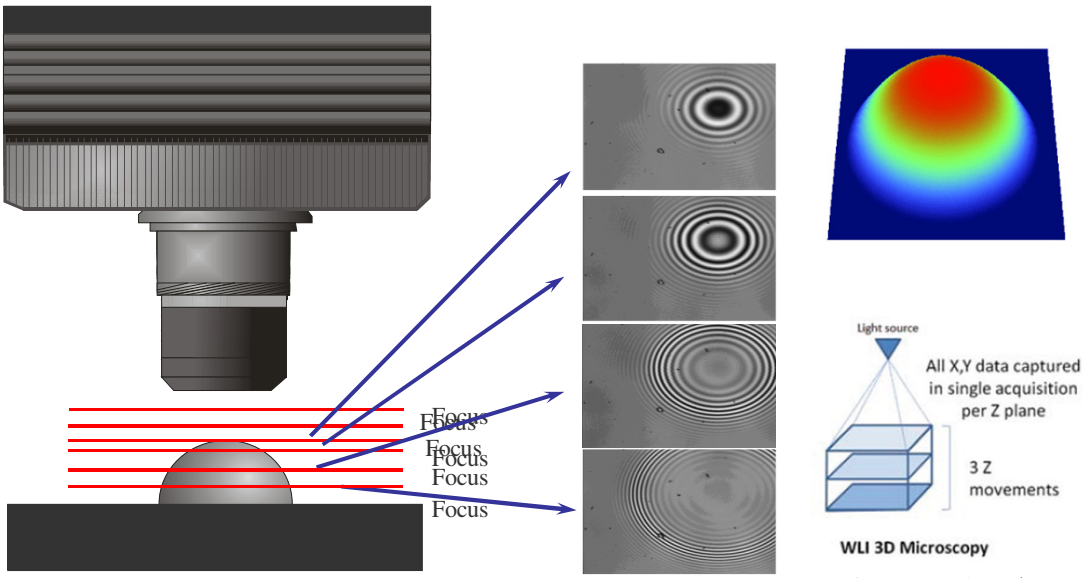
Optical Path Difference (OPD)
- difference in optical path lengths that beams travel in Reference and Test arms.

- The expanded beam exiting from the light source is divided by a Beamsplitter into two beams.
- One beam is reflected from the reference mirror, and the other one from the sample.
- These two beams are recombined by the beamsplitter to interfere.
- The imaging lens images the interferogram onto the CCD camera.

Demonstration of 3D Optical Scan
Step Height Measurement

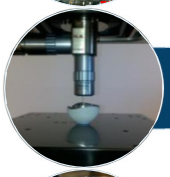


Demonstration of 3D Optical Scan
Hemisphere Measurement



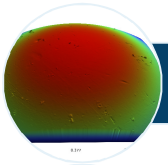
Universal
Easy Access & All type of surfaces

Safe operation @ high magnifications

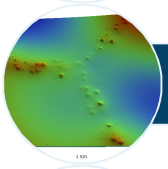


Improve access with LWD objectives

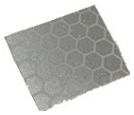
Access vertical walls

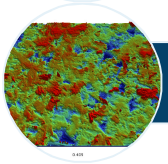


Shiny & Curved



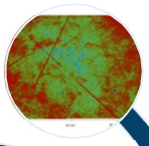
Transparent





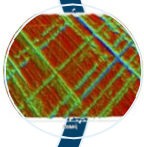
Black color

Metrology

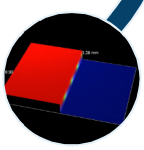


Super smooth mirror Sa=0.1nm

From 0.1nm roughness to mm step



Cross-hatch pattern on fuel engine Sa=0.1µm



1mm step height

Trust in results

Repeatability tests

Step (µm)	1 σ (µm)	1 σ (%)
0.088	0.0001	0.08%
7.319	0.0030	0.04%
46.472	0.0265	0.06%

Measurement Number	Step Avg µm Always Always Step Height	Magnification Always Always Meta Data	Step Avg µm Always Always Step Height	Magnification Always Always Meta Data
1	8.4119	4.964	8.42476	49.8
2	8.4104	4.964	8.42784	49.8
3	8.4143	4.964	8.42597	49.8
4	8.4128	4.964	8.42856	49.8
5	8.4075	4.964	8.43183	49.8
6	8.4182	4.964	8.42962	49.8
7	8.4105	4.964	8.42864	49.8
8	8.4125	4.964	8.42883	49.8
9	8.4159	4.964	8.42984	49.8
10	8.4117	4.964	8.42920	49.8

1σ = 0.003µm *1σ = 0.002µm*

02

High magnification objective

Optical resolution and lateral sampling

Two major lateral resolution limitations

- **Optical diffraction**

  Higher NA optics and shorter wavelength provide better feature measurement

- **CCD pixels**

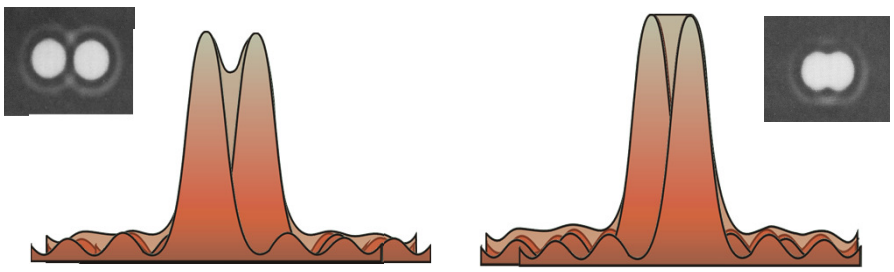
  Higher number or smaller size pixel cameras does not necessarily provide better feature measurements

Objectives

Wide selection of objectives for your application

- Standard objectives 2.5x, 5x, 10x, 20x, 50x, 115x
- Long working distance (34 mm): 2x, 5x, 10x, 20x
- Large area: 1x

Optical resolution

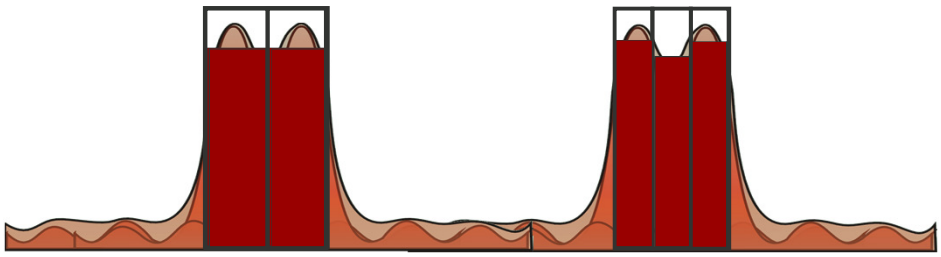


2-point optical resolution for incoherent light:

Rayleigh criterion
Points separation = 0.6 l / (NA)

Sparrow criterion
Points separation = 0.47 l / (NA)

Lateral resolution limits



System is limited by detector

Larger pixels limit image delivered by optics

System is limited by optics

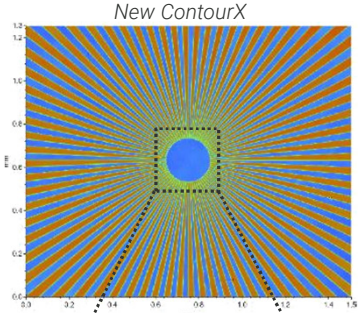
More or smaller pixels do not help in resolving smaller features

Large Field of View for new 5M CCD Combined with better lateral resolution

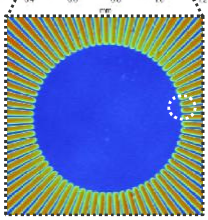
New ContourX

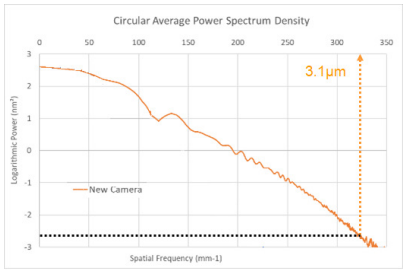
10x objective with 0.55 zoom

Full Image



Digital Zoom In





High repeatability

Mode	Step (µm)	1 σ (µm)	1 σ (%)
PSI	0.0884	0.0001	0.08%
USI	7.4745	0.0030	0.04%
VSI	46.4722	0.0398	0.09%

115x Objective Overview

- Designed for use on all Bruker 3D microscopes
- Increases the ability to measure steep slopes on smooth surfaces
- Increases the ability to measure small features

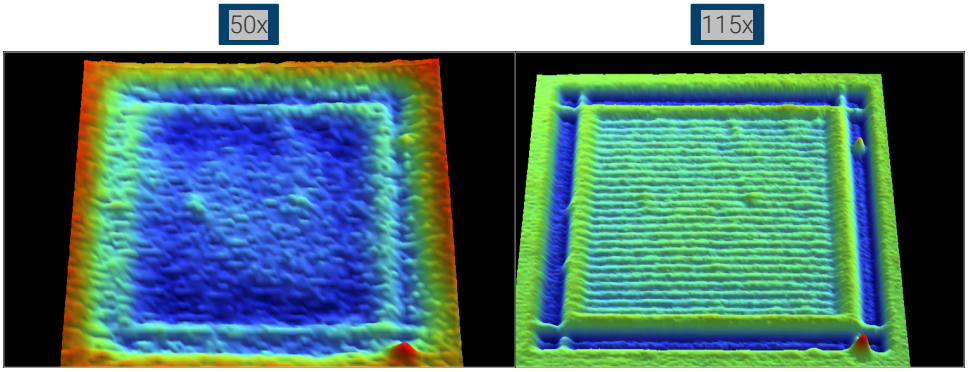
Specifications

Feature	Specification
Magnification	115x
Interferometer Type	Mirau
Numerical Aperture	0.80
Working Distance	0.7 mm
Depth of Field	0.8 µm
Reference Surface Reflectivity	20%
Maximum Theoretical Slope on Smooth Surfaces	53 degrees
Lateral Resolution Using Sparrow Criterion	314 nm on Bruker ContourGT series and Bruker NT9XXX series 3D microscopes; 375 nm on prior models

Keys to Measurement Success

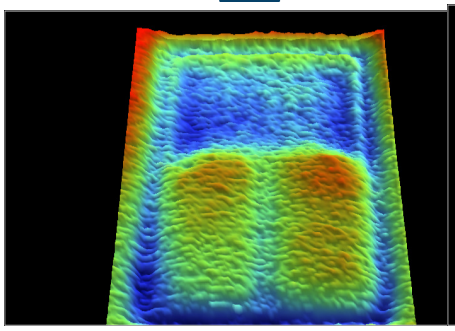
- The 0.7mm (700um) working distance requires close proximity to the sample surface
  - This short working distance greatly increases the risk of contacting measurement surface
  - It is possible to make a long enough VSI scan to contact the measurement surface
- *The reference mirror inside the objective must occasionally be refocused*
- Due to small depth of focus autofocus must be used for PSI measurement to get the best results
  - Reference generation and removal should also be performed

Results
200nm Horizontal Lines (1x FOV-USI)

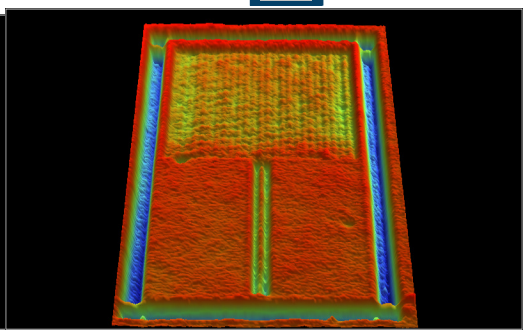


Results
200nm Horizontal Lines (1x FOV-USI)

50x

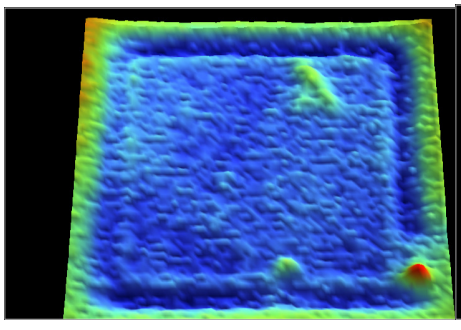


115x

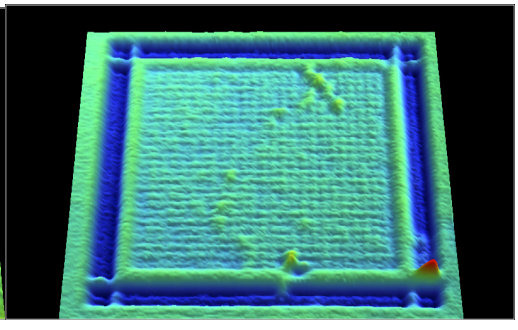


Results
200nm Grid (1x FOV-USI)

50x



115x

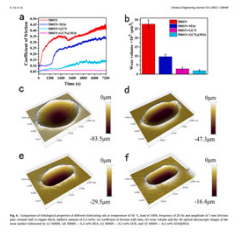


03

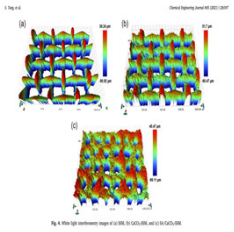
What are the top 8 applications by Bruker WLI in publication?

3D OM CUSTOMER PUBLICATION ANALYSIS REPORT

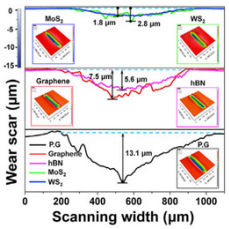
Top 8 applications typical data by Bruker WLI in publication



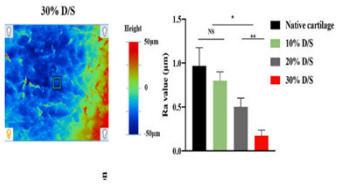
Tribology



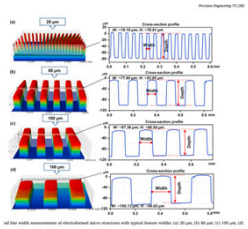
Surface property



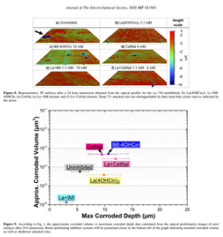
Lubrication



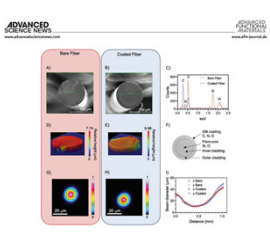
Medical device



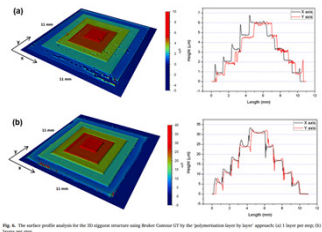
Micro manufacture & Precision machining



Corrosion



Function materials



Additive Manufacturing

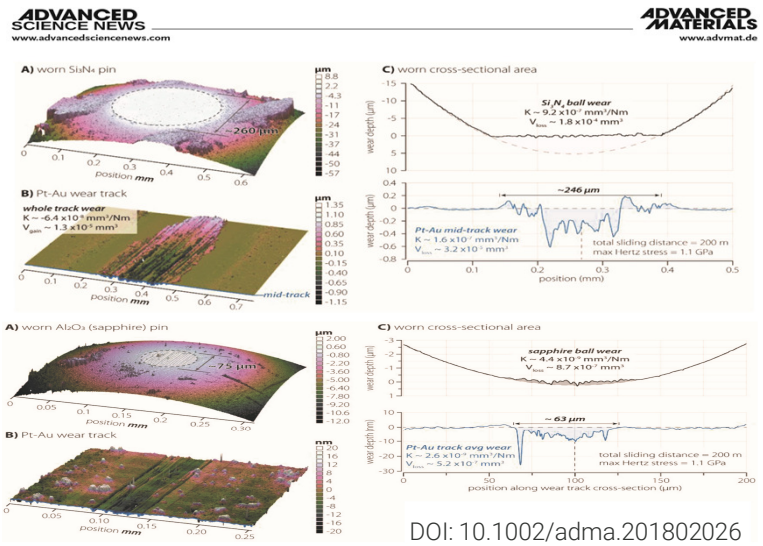
Why is Bruker WLI used for above research? - I

- **1, Tribology:** Quantify wear volume, depth/width of wear track, evaluate precisely without contact; even for wear mechanism studying together with SEM sometimes
- **2, Surface property:** Quantify surface texture/structure for studying Superhydrophobic, Surface Morphologies & Gloss Appearance, Antifouling, Oil/water separation, Superoleophobicity, Self-cleaning, Wettability, Self-healing, Biocompatibility, Anti-icing
- **3, Lubrication:** Quantify wear volume, depth/width of wear track, morphology investigation
- **4, Medical device/Biomaterials:** in-situ, non-contact direct observation; 3D dimensions for Microfluidic device; Surface finishing of stents, implants, etc.; Morphology, roughness for studying Biodegradation, Antifungal Efficacy, Adhesion strength, Functionalized surface, Antibacterial, Osteogenic

Why is Bruker 3D OM used for above research? - II

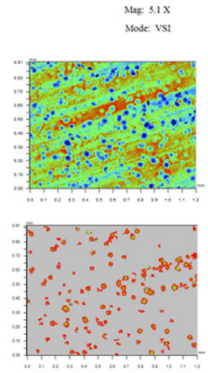
- **5, Micro manufacture & Precision machining:** 3D dimensions of device/structures, quantify surface finishing for ultra precision machining method validation, parameter optimization; Frequently used in laser texturing, precision drilling, ablation, cladding, and single-point diamond turning, micro electroforming, injection molding, etc
- **6, Corrosion:** Quantify corrosion depth/profile, corroded volume, for studying pitting, cavitation erosion, fretting corrosion, microbiologically influenced corrosion, galvanic corrosion, tribocorrosion, erosion–corrosion
- **7, Function materials:** Film thickness, structure depth, roughness measurement for electronics/optical/etc film/coating
- **8, Additive Manufacturing:** Surface topography/morphology characterization, process optimization

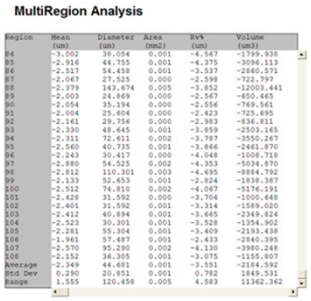
Tribology study

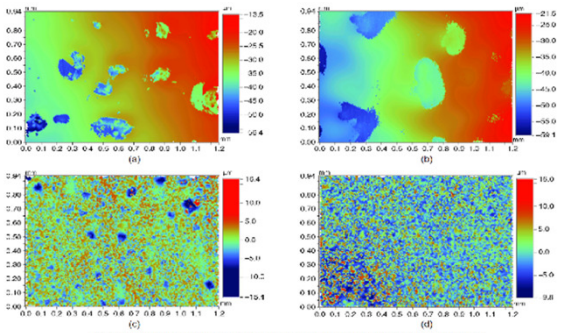


DOI: 10.1002/adma.201802026

Corrosion study

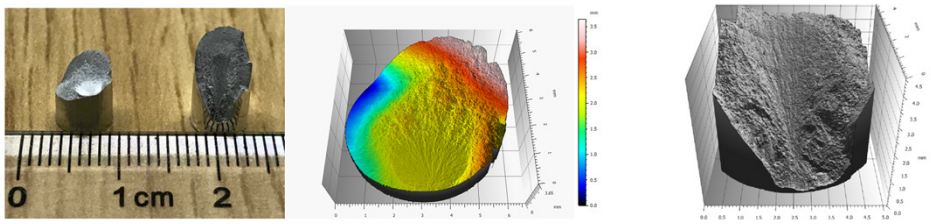




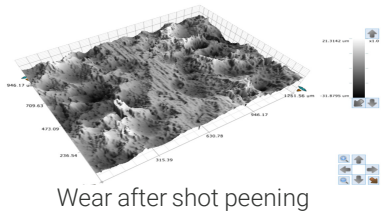


Two-dimensional views of inhibitor films for CI-A and CI-C after 24 h of static and dynamic exposures.

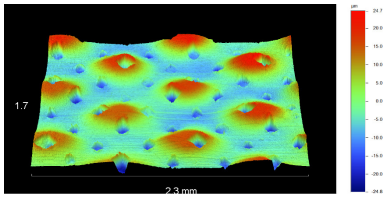
Other typical data by WLI on metal



Fracture analysis



Wear after shot peening



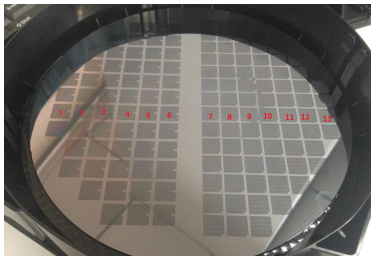
Al Foil for LIBs

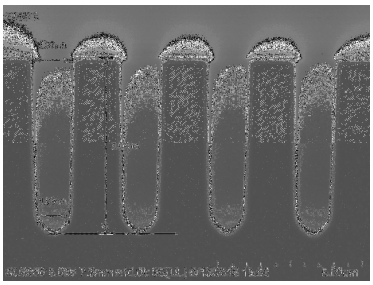
04

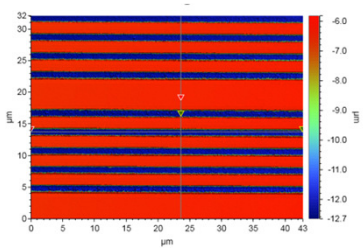
Advanced materials study by 3D OP

Power device

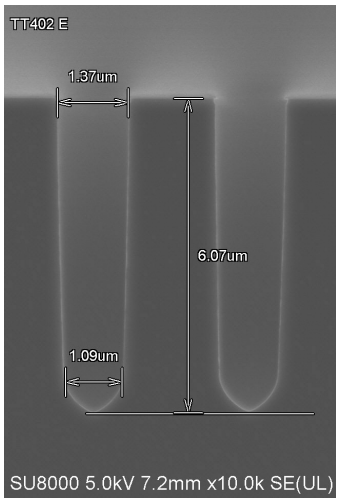
8-inch wafer trenches	SEM Cross section	WLI direct measurement with 115x



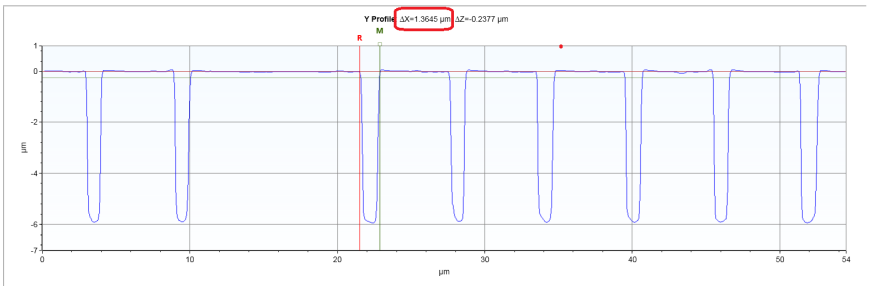




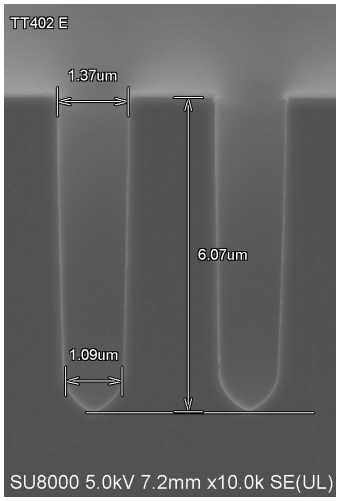
Power device： Top CD, 1.37μm(SEM) vs. 1.36 μm(WLI)



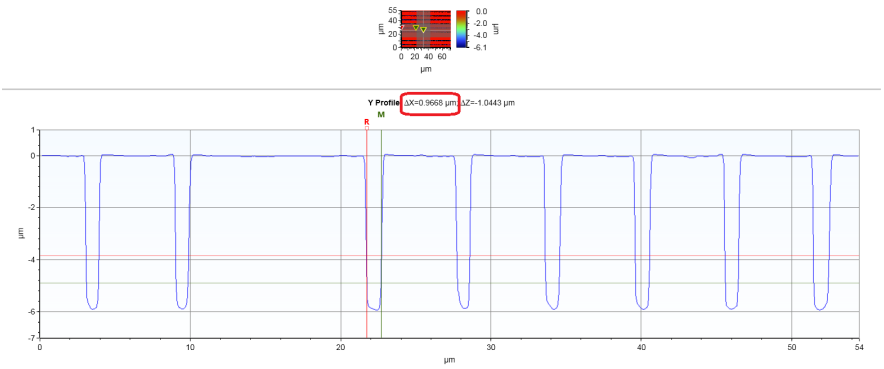
Top CD=1.36μm



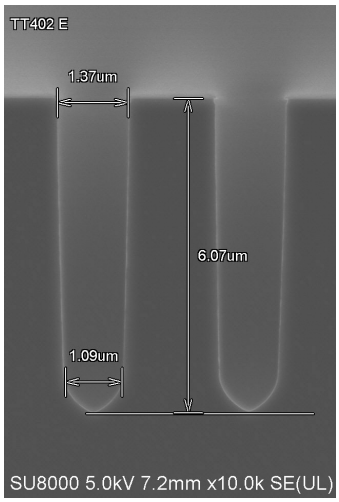
Power device： Bottom CD, 1.09μm(SEM) vs. 0.97μm(WLI)



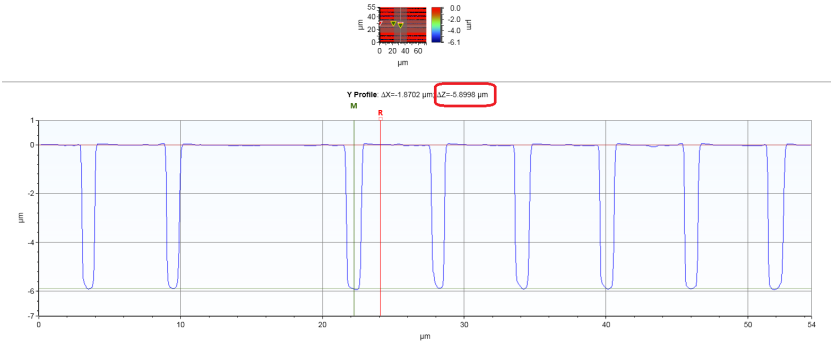
Bottom CD=0.97 μm



Power device： Depth, 6.07μm (SEM) vs. 5.90μm(WLI)

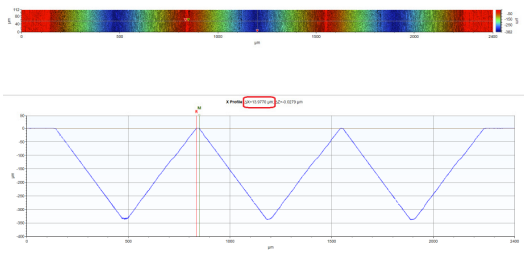


Depth =5.90 μm

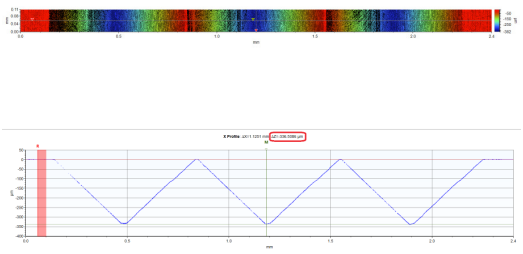


Mold groove: teeth dimensions by 115x objective

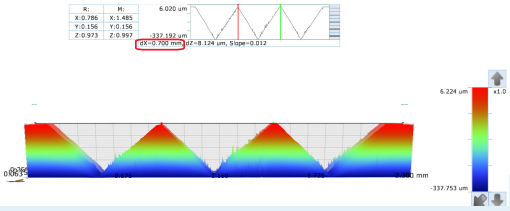
Tooth Width = 13.977 µm



Tooth Depth = 336.509 µm

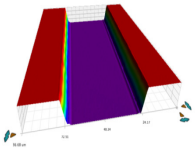


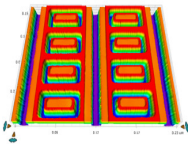
Teeth Pitch = 0.7 mm

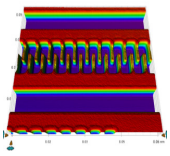


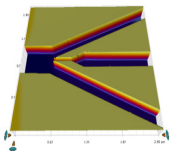
MEMS:

- *Step and Trench Depth/Height*
  - *Volume of trenches, flow cross sections*
  - *Etch Depth Control for Production*
  - *High Aspect ratio structure*
- *Roughness*
  - *Ra indicator for fluid flow w/viscosity and adhesive properties*
- *CD measurements*
  - *Channel spacing*
  - *Flow channel pitch, widths*
- *Film Thickness*





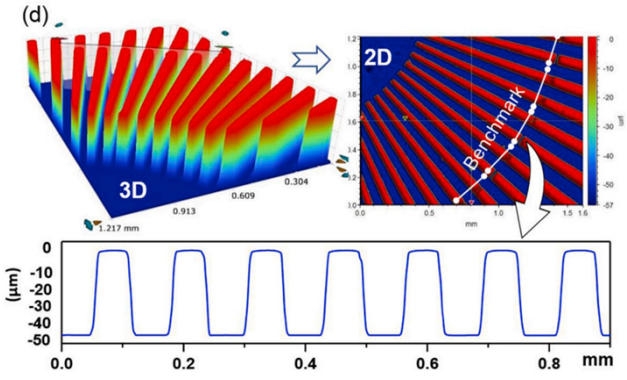




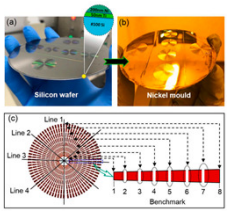
MICRO MANUFACTURE & PRECISION MACHINING: STRUCTURE/FINISHING

微结构内部传质及其对精密微电铸中复形精度影响的研究

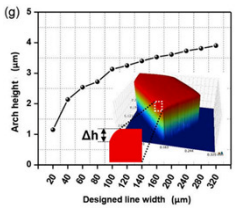
实验验证三维形貌与深宽比数据

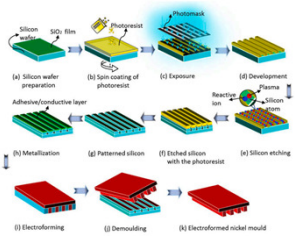


Si片复形到Ni模具



弧边降与设计线宽





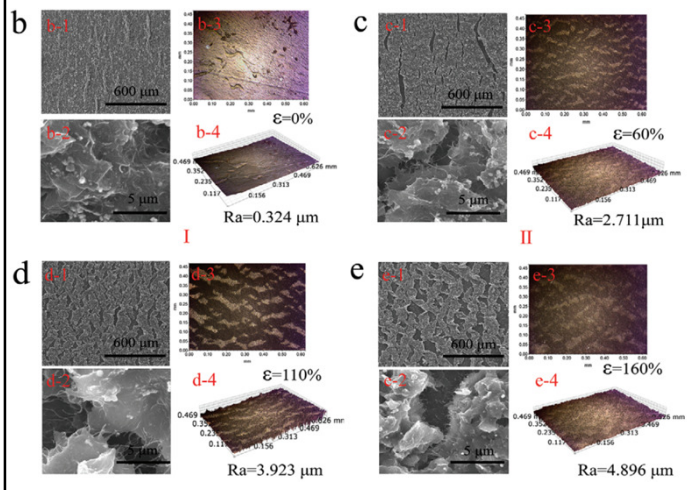
- 微电铸是一种有前途的基于电沉积的精密复制技术，用于制造微结构模具。
- 首次提出了一种新颖的星形图案，其线宽在20-320μm范围，对应于0.16-2.5的深宽比，用于评估传质能力和微结构复制精度。

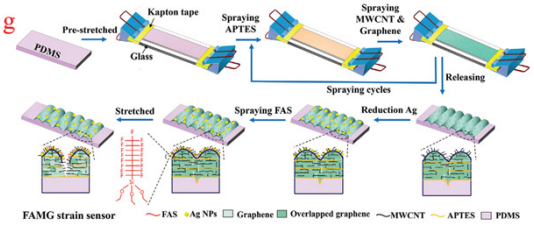
International Journal of Machine Tools & Manufacture 165 (2021) 103717

SURFACE PROPERTY: MORPHOLOGY AND ROUGHNESS

基于Cassie-Baxter润湿状态的高拉伸率和超灵敏应变传感器的抗液体干扰和细菌粘连的策略

不同应变下的形态变化与Ra数据





- 制备了PDMS为基材，涂覆APTES结合层和MWCNT/Graphene导电层的三明治结构，再修饰以Ag纳米颗粒和FAS，形成FAS / Ag / MWCNG / G-PDMS（FAMG）应变传感器。
- 该传感器具有超高灵敏度（在液体干扰条件下的最大规格系数为1989），宽应变范围（0.1–170%），快速响应时间（150 ms）和1000次拉伸释放周期后的稳定响应。

Adv. Funct. Mater. 2020, 2000398

SURFACE PROPERTY: MORPHOLOGY AND ROUGHNESS

通过细菌诱导的生物矿化技术制备碳酸钙涂层-不锈钢网，有效分离油-水

不同步骤下表面三维形态的变化

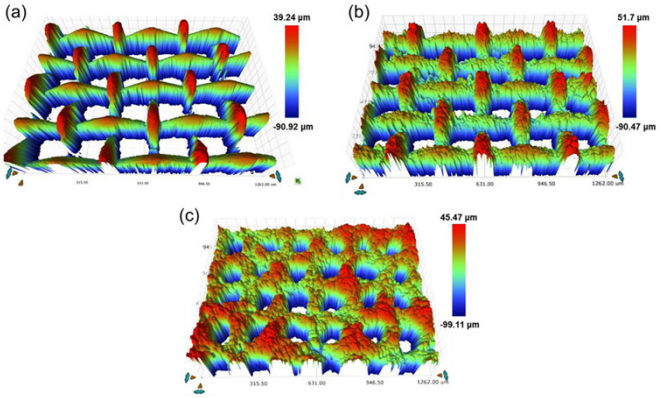
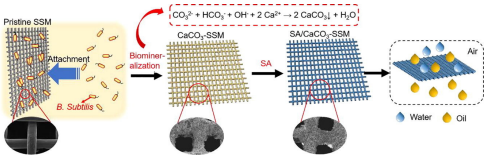


Fig. 4. White light interferometry images of (a) SSM, (b) $CaCO_3$-SSM, and (c) SA/$CaCO_3$-SSM.

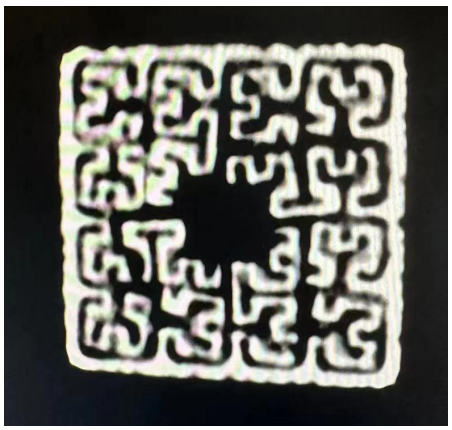
Chemical Engineering Journal 405 (2021) 126597



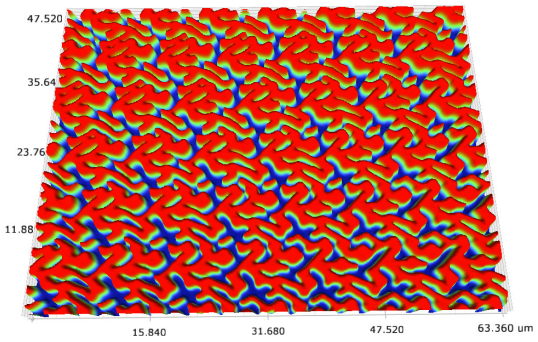
- 介绍了一种超疏水性碳酸钙（$CaCO_3$）涂层不锈钢网（SSM），该网使用细菌诱导的生物矿化技术制造，随后使用硬脂酸（SA）进行表面改性。
- 基于生物矿化作用，在SSM表面形成连续，致密且厚实的$CaCO_3$涂层，形成超亲水性网孔（$CaCO_3$-SSM）。
- 对超亲水$CaCO_3$-SSM进行SA改性，以获得超疏水的网眼（SA / $CaCO_3$-SSM）。
- SA / $CaCO_3$-SSM对各种油/水混合物显示出高的油通量（0.2-9.12×10^4 L·m^{-2}·h^{-1}）和高分离效率（> 94.8%）。

For HKUST device

ribbons/wires ?



Structured patterns



Shape memory alloys

MICRO MANUFACTURE & PRECISION MACHINING: STRUCTURE/FINISHING

不同尺度层级的纳米纹理化技术在光滑但粘滞的柔性表面上实现声流体学器件

~500μm² 面积表面形态，
平行沟槽特征， 3D OM图像

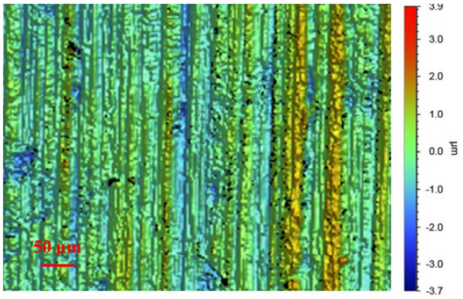
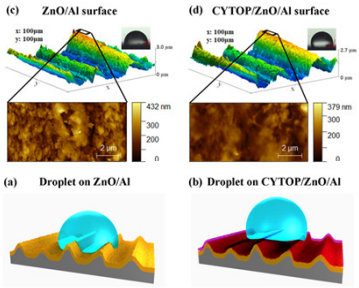


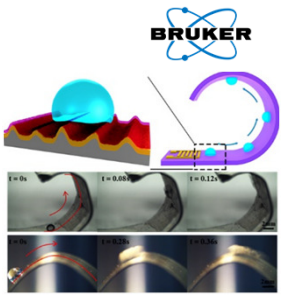
Figure S1. Surface morphology of 600 μm thick Al substrate measured using interferometer. The surface of the substrate comprises of groove patterns, where the average width between two grooves is about 24.9 ± 7.8 μm.

Nano Lett. 2020, 20, 3263−3270

100μm²和5x8 μm² 面积表面形态，
AFM图像



Wenzel state transformed into a Wenzel/Cassie–Baxter mixed state by coating a thin hydrophobic layer of CYTOP. (c) (d) shows that the nanoscale roughness is reduced after the surface is coated with CYTOP.

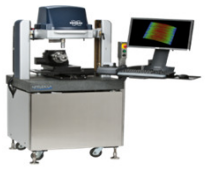


- 驱动液体的能力仍然是智能微系统（如软机器人系统）中的一项基本挑战，在智能微系统中，器件通常需要在各种方向上符合自然或三维立体形状。
- 我们创建了不同尺度层级纳米结构的表面，这些表面同时具有光滑性和粘性。

05

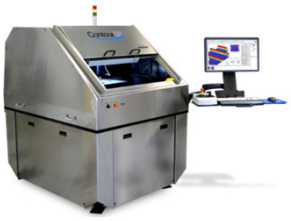
Summary

Bruker Stylus and Optical Metrology
Products



NPFLEX-LA Standalone
斜纹角测试

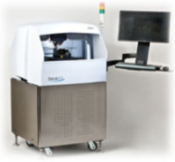
NPFLEX 1000 Standalone
机械零部件测试



Contour SP
半导体封装测试

Insight WLI
晶圆测试

DektakXT
6吋以下台阶仪



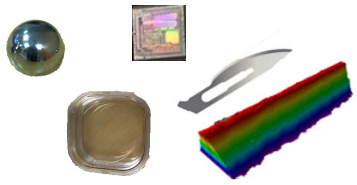
Dektak XTL
12吋台阶仪

ContourX Serial Benchtop
桌面式小型测试平台

ContourX 1000 Standalone
落地式测试平台

Best WLI Metrology solution on market
Robust metrology

Region	R Mean nm	Ra nm
	167.93	74.99
	154.72	25.52
	168.43	48.58
	14.57	69.62
	71.83	47.96
	38.48	47.02

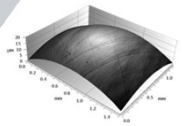


Sub-nm vertical resolution on large step

Normative Report

Any surfaces

Dedicated analysis



45µm step

1µm flatness

100nm coplanarity

ISO 25178 - Roughness (S-L)		
F: Form removed (LS-sphere, R=24.9 mm)		
S-filter (λs): Robust Gaussian (order 2), 2.5 µm		
L-filter (λc): Robust Gaussian (order 2), 0.25 mm		
Height parameters		
Sq	55.5	nm
Ssk	0.87	
Sku	8.86	
Sp	491	nm
Sv	291	nm
Sz	782	nm
Sa	36.5	nm

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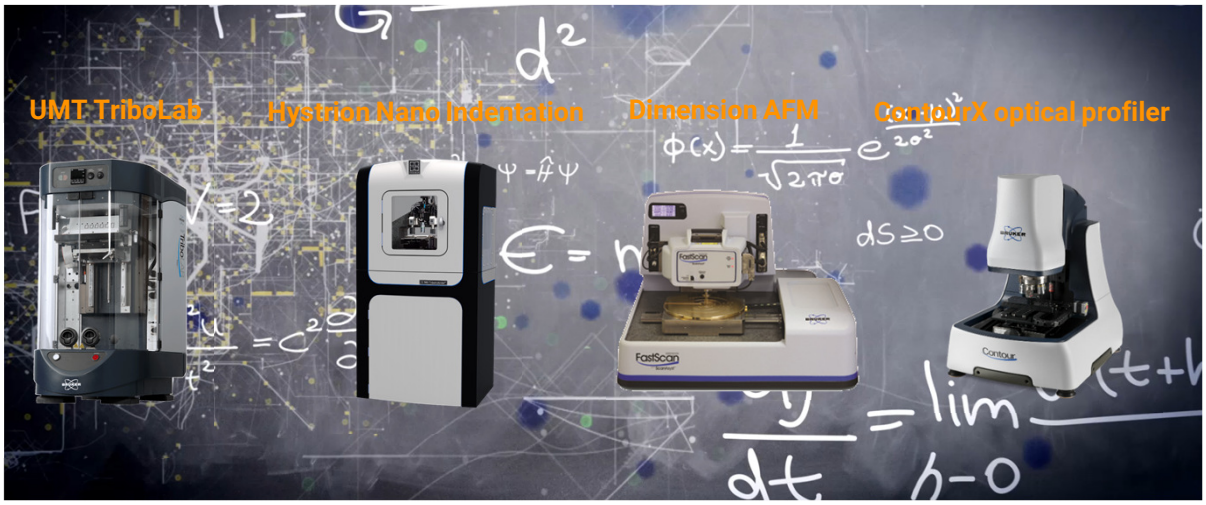
Bruker Nano Surface Metrology test and characterization platform



Thank you!

Name
Email or phone number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