Advances of Bruker White Light Interferometry technique and high magnification measurement application introduction

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Why would you consider White Light Interferometry profiling technique?

Advances of Bruker White Light Interferometry technique

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

High magnification measurement application

Summary
Why would you consider White Light Interferometry profiling technique?
White Light Interferometry
Inherent Benefits

**Vertical resolution**
- **Unmatched** limit: 0.01nm
- Unmatched independent from field of view or/and working distance.

**Lateral resolution**
- Up to 0.38μm with Sparrow criterion
- Preserve optimal resolution from each objective

**Universal**
- Operate in all surfaces
- Easy & Safe access with Long Working Distance
- Robust in all conditions

**Metrology**
- Interferometry certifies step height at metrology labs
- Invented by Bruker to match demanding quality control
Vertical resolution

Sub-nm resolution for all FOV and WD

Field Of View
Working Distance

2.5x objective
Sa = 0.058nm

20x objective
Sa = 0.053nm

115x objective
Sa = 0.057nm

Effective vertical resolution

0.0001 µm

White Light Interferometer profiler

Standard optical profiler

Best vertical metrology

Field of View

Working Distance

0.55x

230x
WLI 3D Microscopy compared to Confocal Microscopy

Figure 1. Diagram outlining different scanning methods used by confocal microscopes and 3-D microscopes. Source: Bruker

Figure 2. (A) Confocal microscopes produce only a strong and narrow signal at high magnification and wider, weaker signals for lower magnification objectives. (B) WLI microscopes provide a constant, narrow signal for all objectives. Source: Bruker

Taken from Quality magazine article
Interferometry, Interferometer: principle

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

• 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.

Optical Path Difference (OPD)
- difference in optical path lengths that beams travel in Reference and Test arms.
Demonstration of 3D Optical Scan

Step Height Measurement

Step Height Sample

VSI

10mm height cone

10.6 mm
Demonstration of 3D Optical Scan
Hemisphere Measurement
Lateral resolution

- 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

From 100nm to 10’s mm

190nm diameter structure

Additive manufactured 50µm powder

100mm sapphire wafer

Ultimate lateral resolution
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

From 0.1nm roughness to mm step

Super smooth mirror Sa=0.1nm

Cross-hatch pattern on fuel engine Sa=0.1µm

1mm step height

Trust in results

Repeatability tests

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<th>Step (µm)</th>
<th>1 σ (µm)</th>
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1 σ = 0.003µm

1 σ = 0.002µm
Advances of Bruker White Light Interferometry technique
Hardware
Optimized for performances

White+Green LEDs

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<th>Std:</th>
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<td>Range</td>
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White LED only

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<th>Std:</th>
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<tr>
<td>Range</td>
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<td>39.792</td>
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Step height repeatability

- Better metrology performances
- Higher repeatability
- Increase reproducibility
- Full automation
- Tailor for 3D metrology
- Stable metrology
- Low reflectivity surfaces
- Top metrology performances

Dual LED

Motorized Tip/Tilt in head

Rigid dedicated supporting frame

Optimized optical path

Anti-Reflective layer with 50x objective
Objectives
Tailored for challenges

Multiple Fold mirrors
- Side wall roughness & waviness
- Diameter as small as Ø32mm
- Depth up to 150mm
- Combined with circumference stitching

Through Transmittive Media
- Encapsulated MEMS
- Environmental control (T, RH,...)
- Challenging High Aspect ratio trenches

Gain unique data
Complete Automation Suite
By default

1. Automatic best starting settings
   Reproducible results
   Robust operation

2. Flexible position definition
   Versatile
   Easy setup

3. On-the-fly complete and multi-analysis data extraction
   Throughput
   Correlation

4. Wide range of automatically saved data
   Topography
   Results
   Final report

5. Direct integration of post automation
   Result transfer
   Archive
   Sync with 3rd party software
Universal Scanning Interferometry
Built-In Expertise, Self-adapting & Universal

Steady & Smooth slopes

High lateral resolution

Ready to be used without expertise

Large Field of View

High reflectivity contrast

Accurate stepped surface

Accurate sub-µm roughness
Unique metrology robustness
Take on every challenge

Rough & Dark
Corrosion pit on black anodized coupon

Rough & Reflective
Round metallic pin

Dark & Reflective
Laser textured surface Laser cut on gold coating

Power of WLI profiler implemented by Bruker
Unique stitching solutions
Throughput & Application specific

Auto-Scan
- Live interruption of vertical scan
- Based on % collected valid topography points

Home Scanner
- Work out spread of topography vs. scan range
- Re-center scan for next scan
- Accommodate surface shape

Stitching
- Annular for tribology & manufacturing
- Cylindrical for tribology & manufacturing
- Spiral for optics

Short time to results
What are the top 8 applications by Bruker WLI in publication?
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
Other typical data by WLI on metal

Fracture analysis

Wear after shot peening

Al Foil for LIBs
High magnification measurement application
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
Optical resolution

2-point optical resolution for incoherent light:

**Rayleigh criterion**
Points separation = $0.6 \lambda / \text{(NA)}$

**Sparrow criterion**
Points separation = $0.47 \lambda / \text{(NA)}$
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
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
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

<table>
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<th>Mode</th>
<th>Step (µm)</th>
<th>1 σ (µm)</th>
<th>1 σ (%)</th>
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<td>VSI</td>
<td>46.4722</td>
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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

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

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

200nm Grid (1x FOV-USI)
Power device

8-inch wafer trenches

SEM
Cross section

WLI direct measurement with 115x
Power device: **Top CD, 1.37 (SEM) vs. 1.36 (WLI)**

Top CD = 1.36 μm
Power device: **Bottom CD**, 1.09 (SEM) vs. 0.97 (WLI)

Bottom CD = 0.97 μm
Power device: Depth, 6.07 (SEM) vs. 5.90 (WLI)

Depth = 5.90 μm
Comparison between SEM vs. WLI

Time

Broken vs. Non-Contact

- **SEM:**
  - Need broken wafer, cost very high

- **WLI:**
  - Direct measurement with non-contact method

![Graph comparing Sample Preparation (minutes) and Measurement / Analysis (minutes) for SEM and Bruker Optical Profiler.](image)
TSV correlation: SEM vs. WLI

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<th>Tr4</th>
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WLI Profiler data

5µm width
43µm depth
Crack width on ceramic specimen

Crack width = 237 nm
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
Summary
Bruker Stylus and Optical Metrology Products

- Contour SP
- Insight WLI
- ContourX Serial Benchtop
- NPFLEX-LA Standalone
- NPFLEX 1000 Standalone
- DektakXT
- Dektak XTL 12吋台阶仪
- ContourX 1000 Standalone
Bruker Nano Surface Metrology test and characterization platform

UMT TriboLab  Hystrix Nano Indentation  Dimension AFM  ContourX optical profiler
Thank you!

Name
Email or phone number