Straight Talk:
Laser and Coherence Scanning 3D Microscope Capabilities

Atomic Force Microscopy
3D Optical Microscopy
Tribology
Automated AFM
Stylus Profilometry
Mechanical Testing, Nano Indentation

Innovation with Integrity
Bruker Nano Surfaces Division
Outline

- **Introductions**
  - Brief overview of 3D optical microscope techniques
  - Common misunderstandings about 3D microscopes based on *interference/coherence* techniques
  - Examples of imaging metrology applications
  - Summary
Introductions
Bruker Nano Surfaces Division

- Scanning Probe Microscopy
- 3D Optical Microscopy
- Stylus Profilometry
- Tribology and Mechanical Testing
Introductions
Bruker Stylus and Optical Metrology

• Technology Leadership
  • 60+ Patents
  • 3 R&D 100 Awards
  • 6 Photonics Circle of Excellence Awards

• Manufacturing Excellence
  • Lean, six sigma-based process
  • >100 systems/quarter capacity
  • Rapid production ramp capability

Bruker NSD SOM is part of Bruker Materials (BMAT), a division of Bruker
Introductions

Speaker

Matt Novak, Ph.D.
Manager, Applications Development
Stylus and Optical Metrology
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- Applications at Bruker (approaching 3 years)
- Industry experience (~17 years) optical engineering, fabrication and metrology
- Earned Ph.D. working in private sector metrology capital equipment
Why “Straight Talk?”
Balanced Information on 3D Microscopes

Capital metrology equipment is an **investment** in…

- **Money**
  - Search for and Purchase Equipment

- **Time**
  - Tool Training and Learning

- **..to increase Productivity**
  - Value from metrology

Experience shows industry partners have lost all three of these due to some more prevalent misunderstandings.
Who Will Benefit?

*Intended Webinar Audience*

- Technicians, engineers, and researchers faced with choices about metrology with 3D imaging microscopes

- Those that have heard it is difficult to use 3D microscopes based on *interference* technology

- People who have had poor results from 3D microscopes based on *interference*

- *LSCM* users who like the performance but need faster images for larger areas
Key Value from Webinar
After the Presentation You Will...

- Be aware of 3D microscope techniques for metrology at \textit{nm}, \textit{\mu m} and \textit{mm} scales

- Know why 3D microscopes based on \textit{light coherence} are among the world’s fastest and most capable for all ranges

- Be able to decide with \textit{confidence} whether this type of 3D microscope is right for your needs

- Know the value delivered for accurate, gage capable imaging metrology by this core technology
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Overview of 3D Optical Microscopes
Example Technology Implementations

You may be familiar with or have heard of…

- Digital Scanning (DSM)
- Axial Chromatic Confocal
- Laser Scanning Confocal (LSCM)
- Spinning Disk Confocal (SDCM)
- Coherence Scanning Interference (CSIM)
- White Light Interference (WLIM)
- Focus Variation

3D optical microscopes – choices abound!
Overview of 3D Optical Microscopes
Focus on Two Key Industry Technologies

**LSCM**
- Two Sensors (CCD and PMT sensor for laser scan)
- Raster Scan XY with laser for each image section
- Scan optics (sample) vertically to build 3D

**WLIM**
- CCD is image and height data sensor
- Full image section obtained at camera frame rate
- Height data computed from interference information
LSCM Laser Scanning Microscope
Brief Overview of Operation

White light source
Half mirror
XY Scanning Assembly
Half mirror
Laser
Condensing lens
Pinhole
Sample
PMT Sensor

Light intensity builds height map
WLIM 3D Optical Microscope

Brief Overview of Operation

Coherent light interference builds height map
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Common Misconceptions – WLIM
Straight Talk on Various Topics

You may have heard someone say WLIM 3D microscopes...

- ...are hard to use
- ...can’t measure steep slopes or roughness
- ...can’t provide color images
- ...can’t measure low reflectance surfaces
- ...have poor signal because “out of focus” light intrudes

In reality end users will find WLIM 3D microscopes...

- ...are fast, easy to set up
- ...can measure 60° + slopes and roughness
- ...can image with color CCD
- ...can measure surfaces with <0.05% reflectance
- ...have excellent SNR, resolution and accuracy
Common Misconceptions – WLIM

Key Technical Concepts

- Next slides show **key concepts** about technologies (LSCM and WLIM)

- Concepts illustrate how 3D microscope systems under discussion address 3D areal measurement

- Focus on key concepts will help you decide which technology will provide fastest, highest quality data best suited for your needs

- Other misunderstandings about WLIM systems will be addressed with example applications
LSCM 3D Optical Microscope Key Point
Broader Intensity Signal, Sharper at High Magnification

Practical Implication: Highest accuracy data at high magnification and image stitching
Good for single FOV applications or applications where vertical resolution is unimportant, speed not critical
Practical Implication: Highest accuracy data on areas of interest obtained fastest at lowest magnifications. Great where a large area with good resolution is required, speed is critical.
LSCM and WLIM Comparison Key Point

Methods of 3D Image Acquisition

Practical Implication: Imaging extended areas at useful vertical resolution is fastest with WLI 3D microscopes

Larger vertical sample range - greater WLIM speed advantage
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3D Microscopes Applications
Ground Shaft Defect, Automatic Detection

1.7 mm x 2.3 mm area

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Skewness: 0.729  0.314  0.378  -0.291  -0.538  0.547  -0.858  0.328
Min: 649.549  34.818  -45.392  4.198  14.526  -76.579  -3062672.500  34.312
3D Microscopes Applications
Roughness, Pitch, Thread Depth

Misconception – 3D WLIM systems are hard to use and can’t measure slopes

- Hard to set up
- Need to worry about tilt/tip of stage
- Hard to find “fringes”
- Can’t measure steep angles

How do I set up to image something like this??
3D Microscopes Applications
Roughness, Pitch, Thread Depth

Reality
Vertical scan ~ 700 microns
Angle 55.1°
Time to Data < 30 seconds
(place part, find focus, measure)
3D Microscopes Applications
Smooth, Steep Surfaces, High Magnification

Misconception – 3D WLIM can’t measure steep smooth slopes or small scale lateral features

• Can’t measure smooth steep surfaces

• Can’t resolve less than ~ .5 μm

How do I measure something like a Patterned Sapphire Substrate (PSS)??
Reality

PSS can be measured using 3D WLIM
~ 15 µm x 15 µm FOV (115X)
Time to Data < 7 seconds per wafer site
(auto focus, measure)
3D Microscopes Applications
Roughness Metrology

Misconception – 3D WLIM can’t measure surface roughness

- Can’t correlate to stylus measurement of Ra
- Can’t properly image any machined surfaces
Reality

Roughness can be measured using 3D WLIM

ISO 4287 and 4288 standards ensure comparisons

ISO 25178-2 for 3D areal data
**3D Microscopes Applications**  
*Low/Variable Reflectance Step Metrology*

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**Misconception – 3D WLIM systems cannot measure low and different reflectance samples**

- Dark plastic, black materials can’t be measured
- Low reflectance causes problems for 3D WLI microscopes

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How do I image and measure areas of high and low reflectance, like this?
3D Microscopes Applications
Low/Variable Reflectance Step Metrology

Reality

3D WLIM can image low/variable reflectance samples

USB insertion Depth ~450 µm
Over 4 mm x 4 mm area
Z resolution ~ 3 nm

Time to Data ~ 40 seconds

(place part, focus, measure)
3D Microscopes Applications
Example Color Imaging + Metrology

Misconception – 3D WLIM systems cannot produce a color image

- Monochrome only 3D WLI systems can’t measure and image in color
- Can’t tell materials apart in WLI systems

How do I image this and see colors as well as height?
3D Microscopes Applications

Cu Wire Bond Cavity Depth, IMC Formation Inspection

Reality

3D WLIM can image color

Wire Bond Cavity, Depth ~ 1 µm

Time to Data < 15 seconds

Color image using interferometric objective
3D Microscopes Applications
Example Diffuse Surface Imaging + GR&R

**Misconception – 3D WLIM systems provide poor signal on low reflection/dark/diffuse surfaces**

- "Quasi confocal" systems suffer from poor signal due to light pollution
- Difficult to measure diffuse or rough surfaces accurately

How do I image this and obtain meaningful metrology data?
3D Microscopes Applications

Example Diffuse Surface Imaging + GR&R

Reality

3D WLIM can image diffuse surfaces over large area

Sensor Depth ~ 30 µm

GR&R < 5% for production standard Isl and usl

Time to Data < 30 seconds

(place part, focus, measure)
3D Microscopes Applications
Microfluidic Example Trench + Defect

- Geometries conducive to 3D imaging metrology
- Trench widths, depths on order of few to ~ 25 µm

Etched Si
1.5 µm x 7 µm channels with defect (center)

Time to data < 10 seconds with 3 nm vertical resolution
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Summary

• Described general 3D optical microscope techniques with focus on LSCM and WLIM

• Presented common misconceptions about WLIM systems

• Gave key points for LSCM and WLIM systems to consider in choices for your work

• Showed examples of imaging applications for metrology from a few different areas and how 3D WLIM can meet those needs
Questions and Answers
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