

Semiconductor Wafer Inspection & Custom Solutions for Microsoft USYD

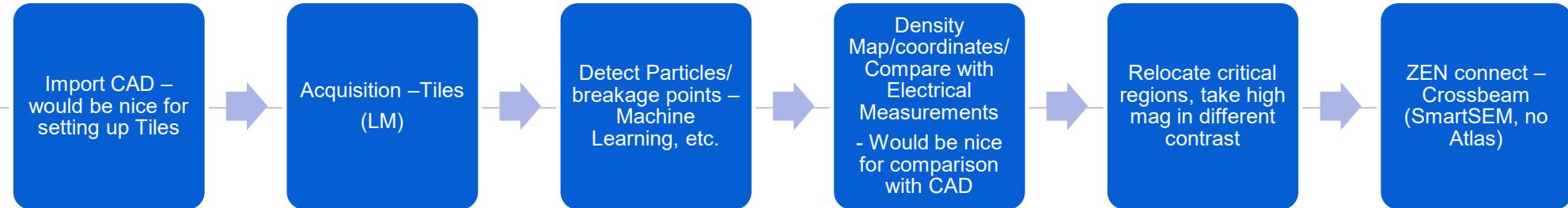


Kelvin Loh

Product & Applications Sales Specialist (APAC), Materials LM & CSEM

2021-03-26

For Discussion



1. **Sample Type:** Wafer, Chips
2. **Sample Size:** Max 6" Diameter
3. **What type of measurements needed:**
 - a) Particle Inspection (mainly resist residue, not likely metals)
 - b) Identify breakage points
4. **What type of analysis needed after imaging:** PI: density map across wafer. Breakage points: coordinates (to know which devices fail, compare with electrical measurements, CorrMic), relocate those points and take high mag.
5. **Size of ROI to scan:** entire 6" wafer, or typically 120x120mm
6. **Size of Smallest Feature (Resolution):** existing objective lens magnification – Olympus 10x, 50x with zoom. 50 nm (EM). Oil is out. **C-DIC could be possible**
7. **Contrast Methods Needed:** existing contrast? **DF, BF, DIC, POL**
8. **B&W or color images required (TCA – B&W):** B&W is ok, color preferable
9. **Degree of automation needed:** Semi-auto is ok.
10. **Throughput expected:** 1 - 2 wafer a week
11. **Any reports needed :** Link to Question 4 (look at report to compare with electrical, rather than EM for all devices)
12. **Any other requests:**
 - a) CAD (.dwg) files to drive experiments
 - b) Correlate microscopy to ZEISS 540 crossbeam
 - c) dimensional/ surface metrology needs? - ZAPHIRE separate topics if you have any images to try on

Axio Imager Vario

*Examine Large Specimens –
Automated & Compatible with Clean Rooms*

Axio Imager Vario

*Examine Large Specimens – Automated and Compatible
with Clean Rooms*



Microscopes

- Axio Imager.A2 Vario (manual, coded)
- Axio Imager.Z2 Vario (capable of being fully motorized)
- Axio Imager.Z2 Vario (without turret focus)

Accessories

- Hardware Auto Focus
- Linear sensor
- Stages: XY stage, reflected light/transmitted light, 200 × 200 R
- XY stage, reflected light, 300 × 300 R
- Scanning stage, 200 × 300 STEP
- Scanning stage, 300 × 300 STEP



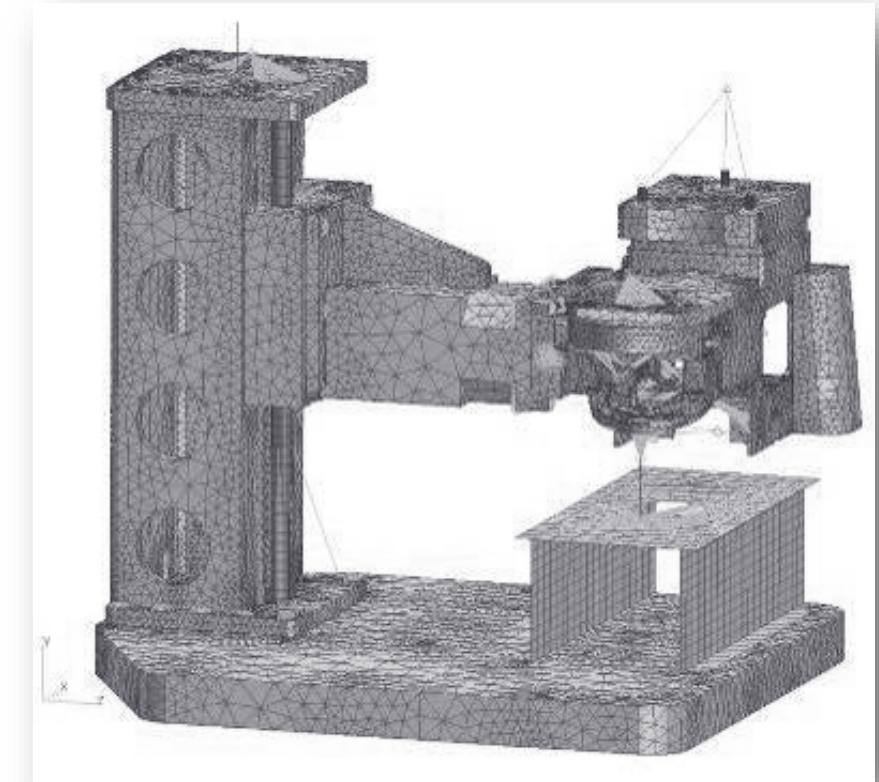
Axio Imager Vario

Unique Features (Vario Only)



Cleanroom Applications

- Upgradeable for clean-room environment
 - ISO 14644 Class 5, equal to US FED STD 209E Class 100



Stable column construction

- 35kg load
- Anti-vibration

Axio Imager Vario

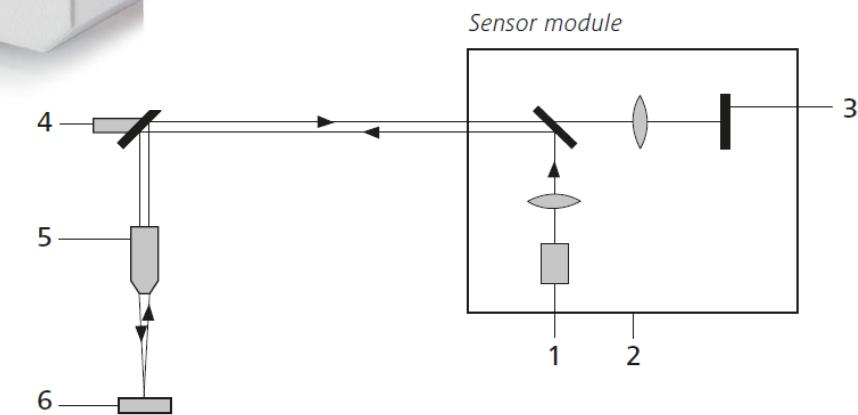
Unique Features



Automatic Component Recognition (ACR)

C-DIC (Circular Differential Interference Contrast)

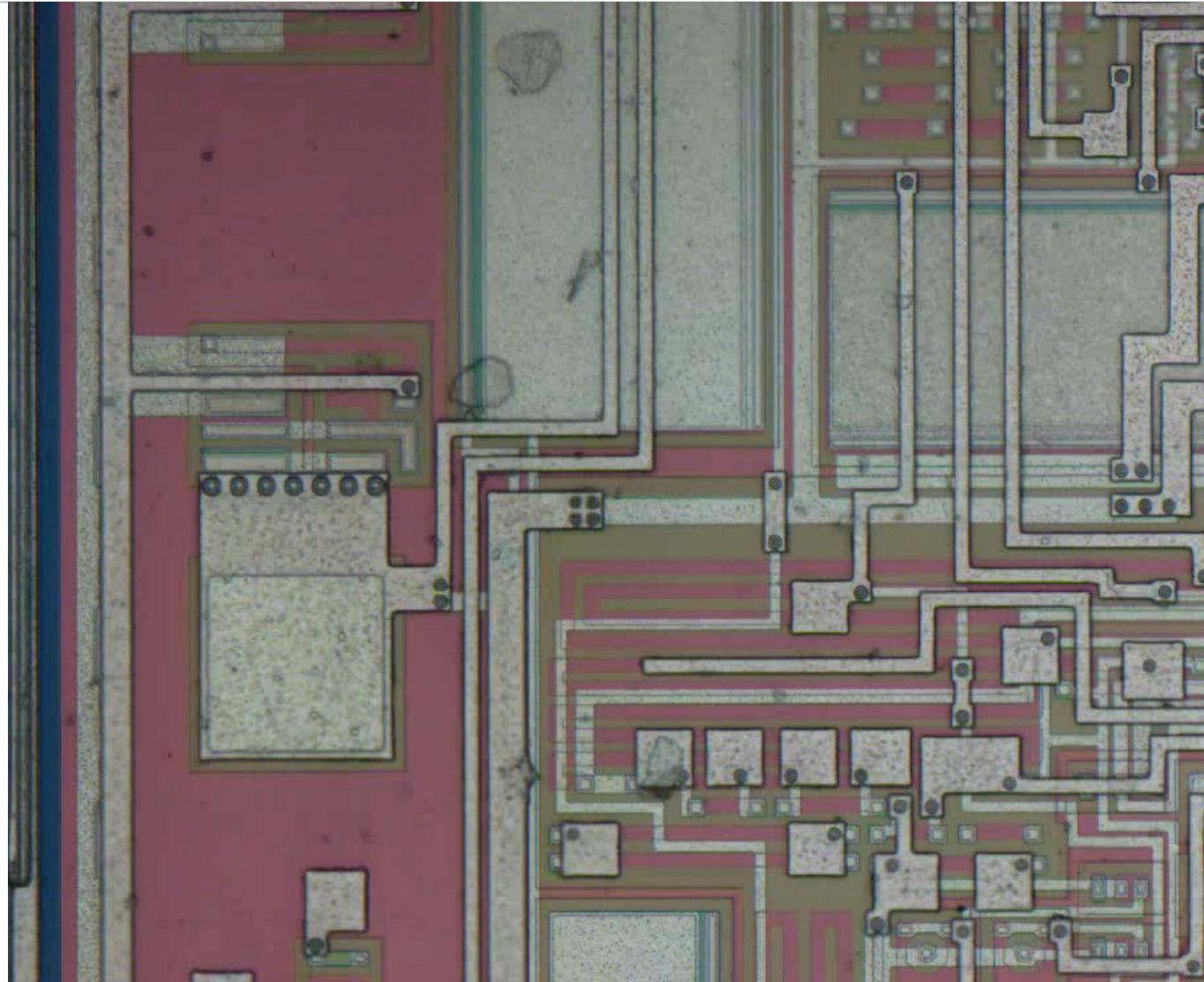
- Unique Contrast Method without need for rotating stage



LED in Hardware Auto Focus system

- fast & accurate focusing of reflective, low contrast specimens

Hardware Auto Focus (HWAF) system



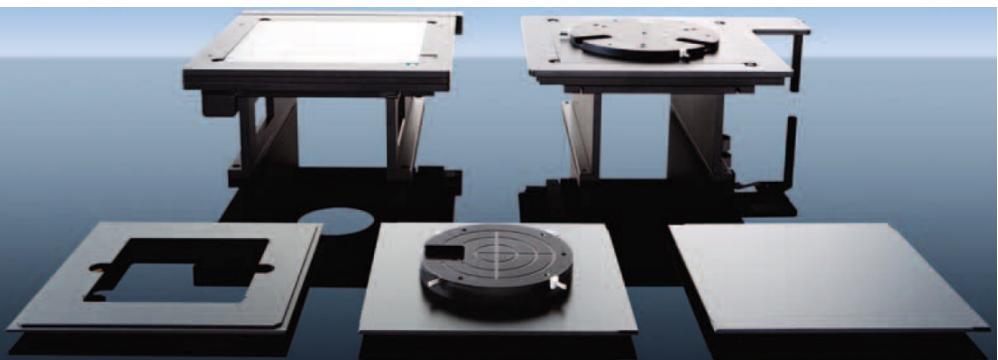
20x Hardware AF on patterned wafer with ~5 μ m structure height

Axio Imager Vario

Key Features (Vario Only)



Large Sample Analysis



Various stages available



Precise motorized nosepiece
▪ z-focus 10nm

Axio Imager Vario

Key Features

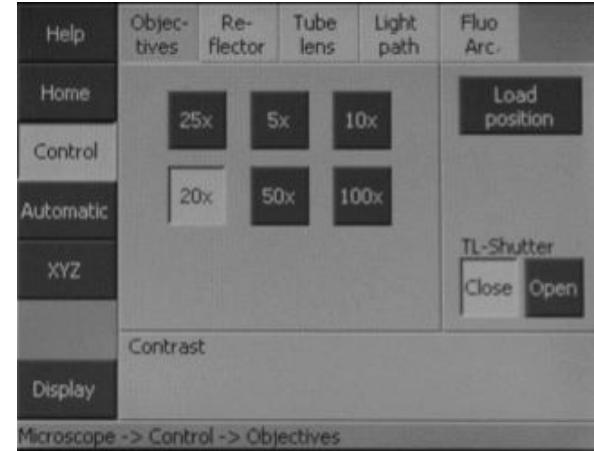


Full motorization (Axio Imager.Z2m)

- Light & contrast managers
- Reproducible settings for Correlative Microscopy & TCA workflow



Comfortable Ergophototube



TFT display with touch screen



Docking Station for TFT Display

Axio Imager Vario

Unique Features (*In addition to Axio Imager*)



Available as Axio Imager Vario - LSM 900 MAT (SCS)

Applications - Cleanroom Inspection with Axio Imager Vario

Cleanroom Applications



Axio Imager Vario microscopes can be upgraded to be used in Clean-room environment.
(Clean-room ISO 14644 Class 5, equal to Clean-room US FED STD 209E Class 100)

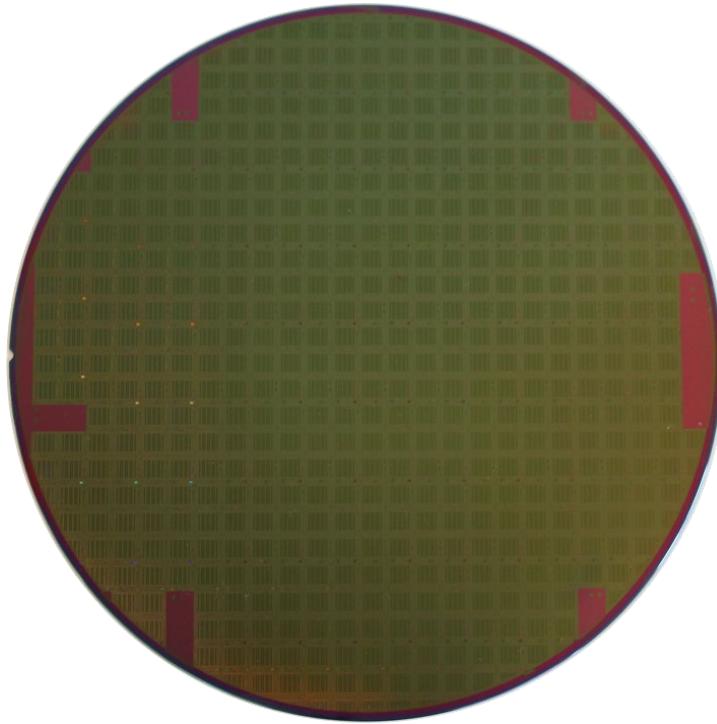
- Nosepiece 7-position HD M27 mot. with **particle protection**
- **Breath and sneeze guard**
- All components packed in **doubled protective film**. Thus, the outer protective film, which may have been contaminated during transport, may be removed in a cleanroom lock
- Scanning stages - special **particle binding grease** used for the sliding bars and spindles



Large Sample Analysis



Wafer and Photomask Inspection



Wafers

- Thin slices of semiconductor material, predominantly silicon, used for fabrication of integrated circuits and other micro devices
- Undergo fabrication processes during integrated circuit manufacturing such as doping or ion implantation, etching and photolithographic patterning

Structures of interest include:

- Particles
- Scratches
- Pattern defects

Important microscope accessory:

- Manual or motorized stage with wafer chuck



Wafer and Photomask Inspection



Photomasks

- Typically transparent fused silica blank covered with a pattern defined by a chrome metal film
- A single photomask defines pattern layer in integrated circuit fabrication
- A set of photomasks is fed into photolithography stepper and selected for exposure

Structures of interest include:

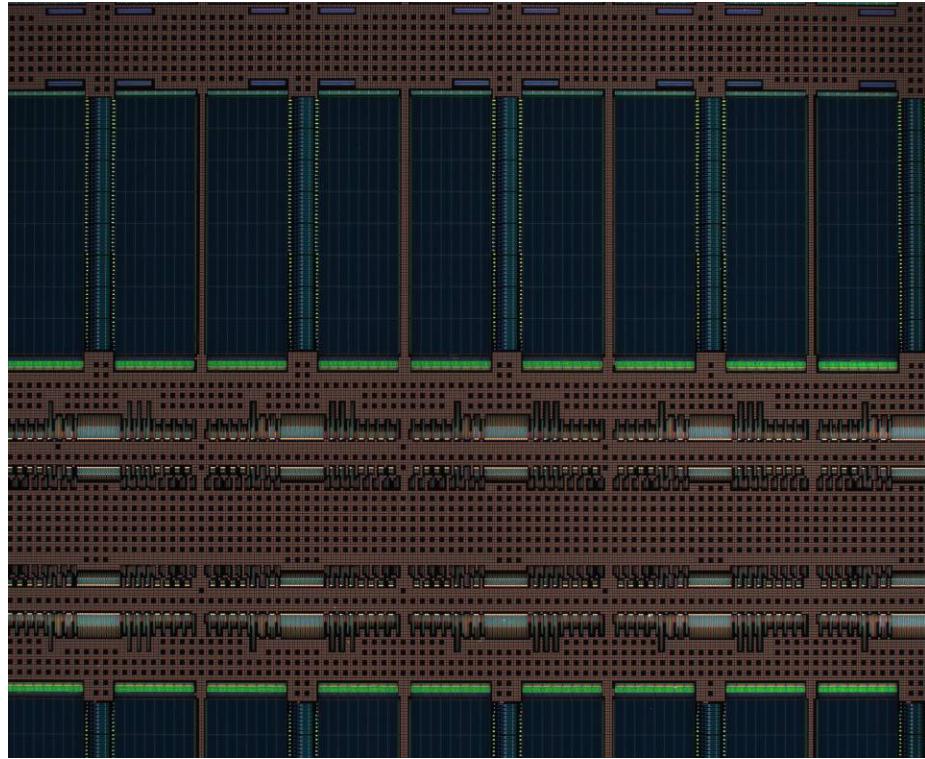
- Chrome spots and particles
- Thin chrome
- Particles on top of chrome

Important microscope accessories:

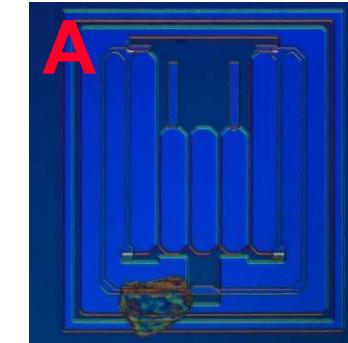
- Manual or motorized stage with mask holder
- Transmitted light module



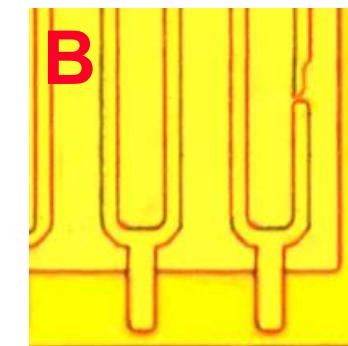
Wafer and Photomask Inspection



Wafer
Reflected light **dark field**
EC Epiplan-APOCHROMAT 10x/0.30



Wafer with Debris
Reflected light **C-DIC**
EC Epiplan-APOCHROMAT
50x/0.95



Pattern Defect
Reflected light bright field
EC Epiplan-APOCHROMAT
50x/0.95

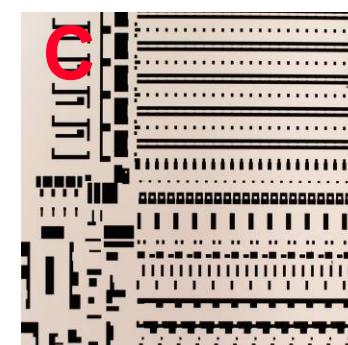


Photo Mask Pattern
Transmitted light bright field
EC Epiplan-APOCHROMAT
10x/0.30

TFT LCD Inspection



TFT LCD

(thin film transistor liquid crystal display)

- Specific type of LCD which utilizes thin film transistor technology
- Used in computer monitors, mobile phones, television sets, personal digital assistants, navigation systems and other devices

Structures of interest include:

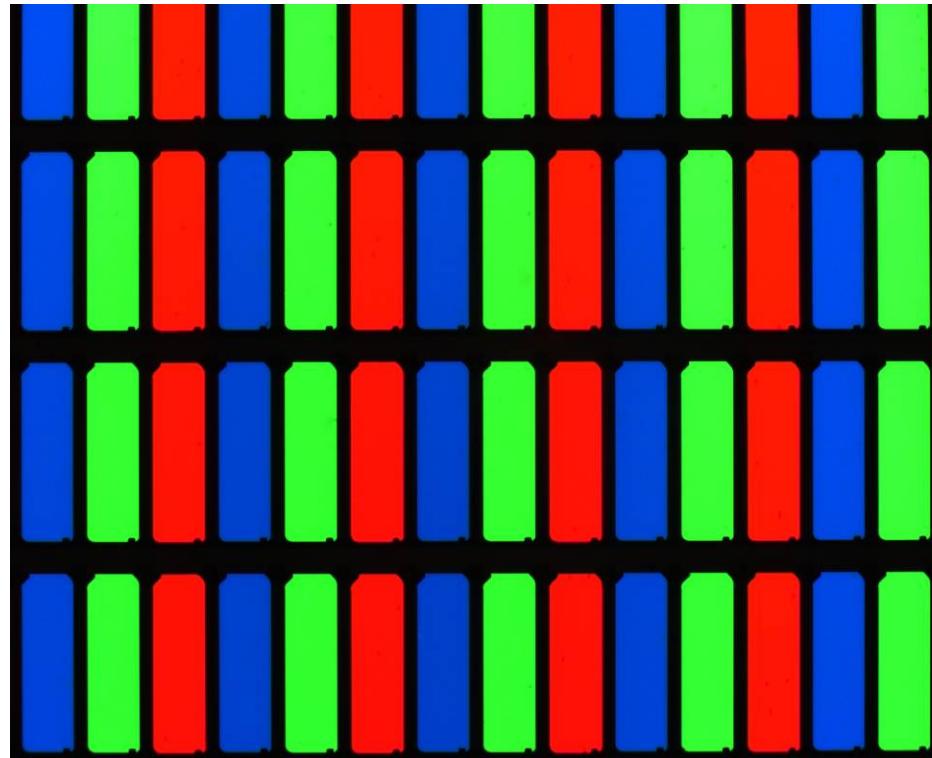
- Full pixel defect
- Dark dot sub-pixel defect
- Bright dot sub-pixel defect
- Microscopic contaminants

Important microscope accessories:

- Manual or motorized stage with glass insert
- Transmitted light module



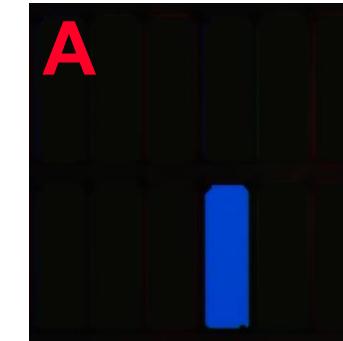
TFT LCD Inspection



TFT Display

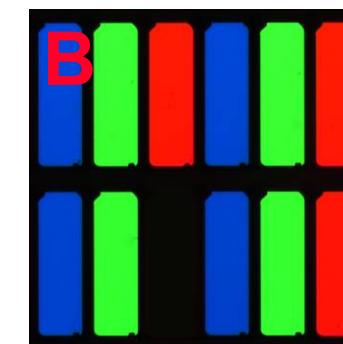
Transmitted light bright field

EC Epiplan-APOCHROMAT 10x/0.30



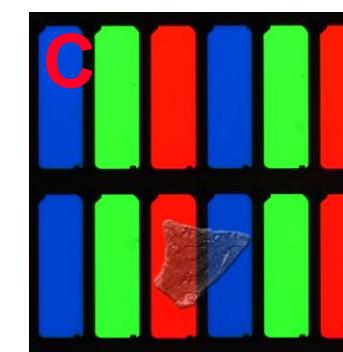
Bright Sub-Pixel Defect

A bright spot on a black background is caused by a blue sub-pixel in the "on" state.



Dark Sub-Pixel Defect

A dark spot on a white background results from a red sub-pixel, which is in the "off" state.



Debris Trapped in LCD

This can result in dark spots, but under the microscope these can be distinguished from an "off" sub-pixel

Crystalline Silicon Solar Cell



Crystalline silicon solar cells are made from material varying in degree of crystallinity and crystal size, most notably mono- and polycrystalline silicon.

- **Monocrystalline Silicon Cells:**
produced from wafers cut from single crystal ingot
- **Polycrystalline Silicon Cells:**
produced from wafers cut from cast blocks

Structures of interest include:

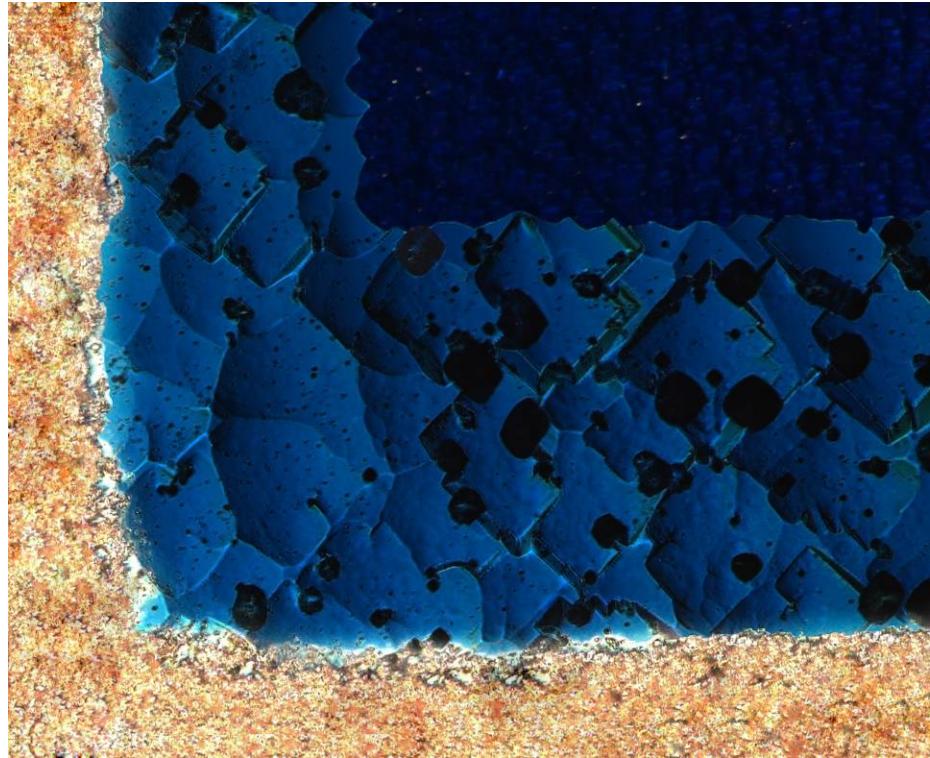
- Surface morphology
- Dimensions of metal contacts (“fingers”)/
“busbars”)
- Dimensions and continuity of insulation
trenches

Important microscope accessory:

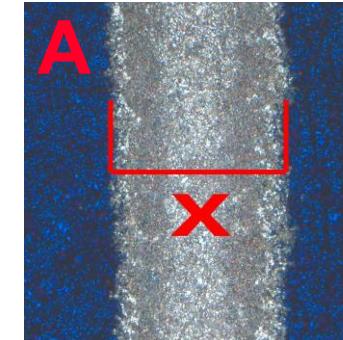
- Manual or motorized stage for reflected light



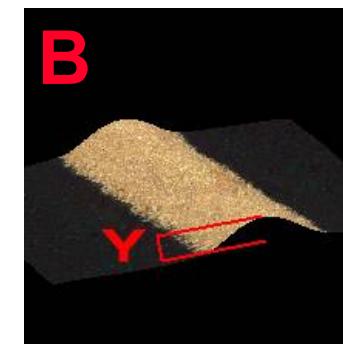
Crystalline Silicon Solar Cell



Monocrystalline Si-Solar cell
Reflected light C-DIC
EC Epiplan-APOCHROMAT 50x/0.95



Silver Finger
on poly-crystalline solar cell
EC Epiplan-APOCHROMAT
20x/0.60

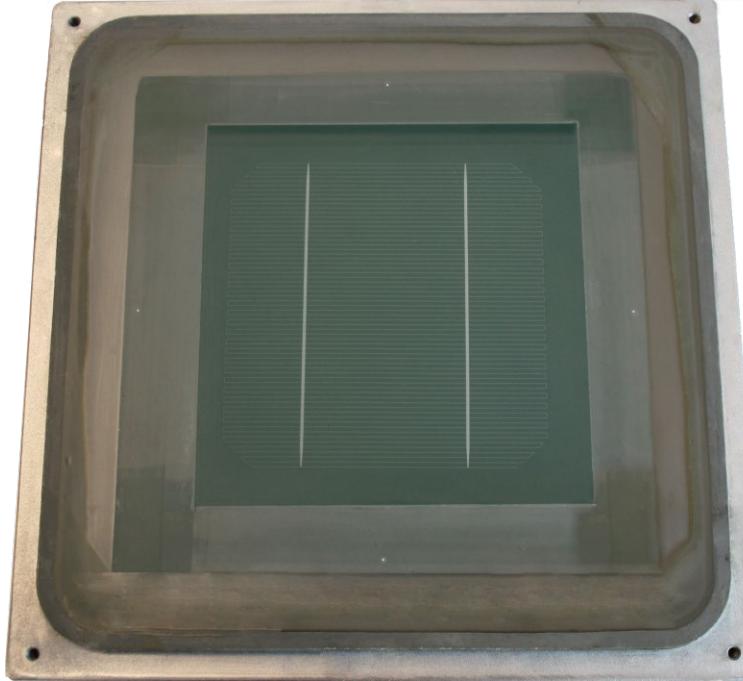


Silver Finger
3D reconstruction on a mono-
crystalline solar cell
EC Epiplan-NEOFLUAR
20x/0.50



Insulation Trench
Laser scribed insulation trench
on monocrystalline silicon solar
cell
EC Epiplan-APOCHROMAT
20x/0.60

Printing Screens for Solar Cells



Printing Screens

- Used to print silver contacts ("fingers" and "busbars") onto silicon solar cells
- Made of porous, finely woven mesh of nylon stretched over aluminum frame
- Areas of the screen are blocked off with a non-permeable material to form a stencil, which is negative of the contact grid to be printed

Structures of interest include:

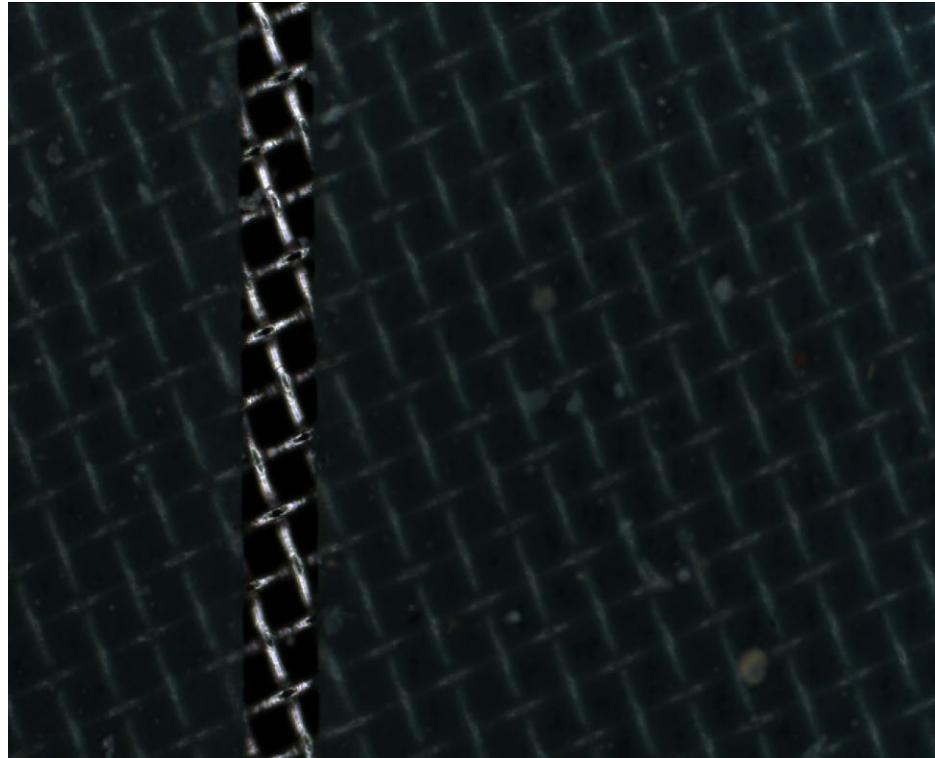
- Height and width of open spaces in the stencil

Important microscope accessory:

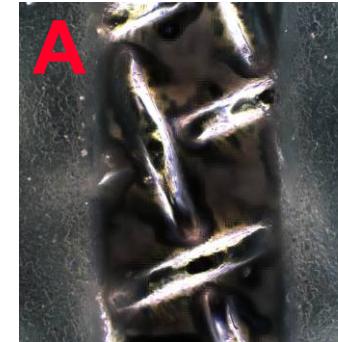
- Manual or motorized stage for reflected light



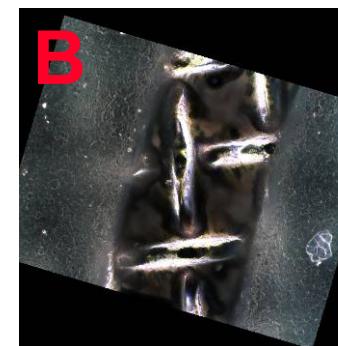
Printing Screens for Solar Cells



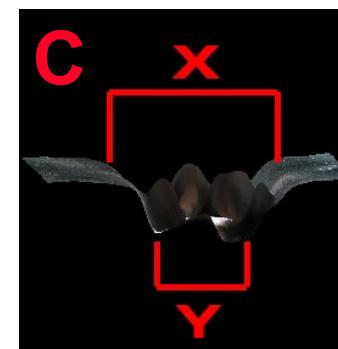
Printing Screen
Reflected light dark field
EC Epiplan-NEOFLUAR 10x/0.25



Nylon Mesh
Reflected light darkfield
EC Epiplan-NEOFLUAR
50x/0.95

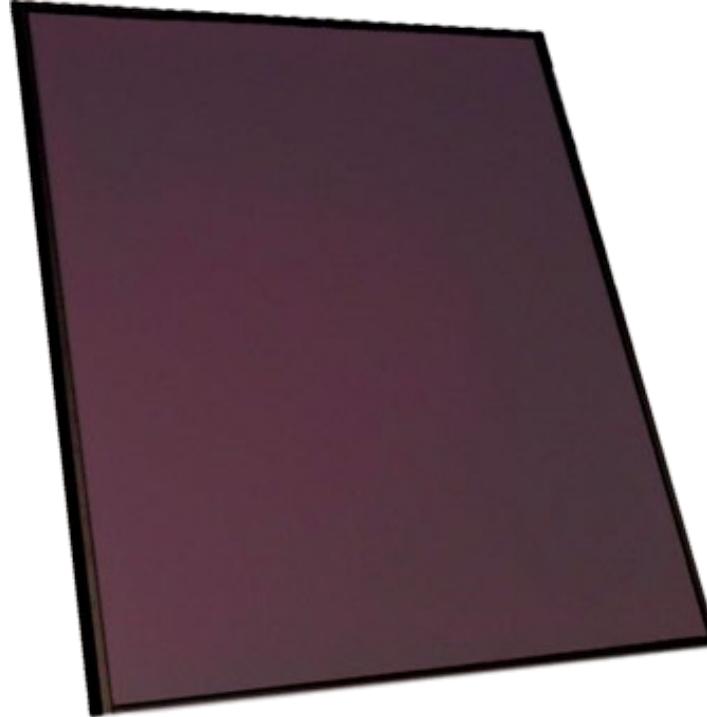


3D reconstruction of Mesh
A z-stack was acquired and converted into a 3D reconstruction.



Rotated 3D Reconstruction
Same 3D reconstruction of the nylon mesh as in B, but shown from a different angle.

Thin Film Solar Cells



Thin film solar cells

- Consist of number of layers providing individual functionalities such as light trapping and photovoltaic properties
- Silicon thin film cells are produced by depositing a silicon layer onto a supporting glass carrier

Structures of interest include:

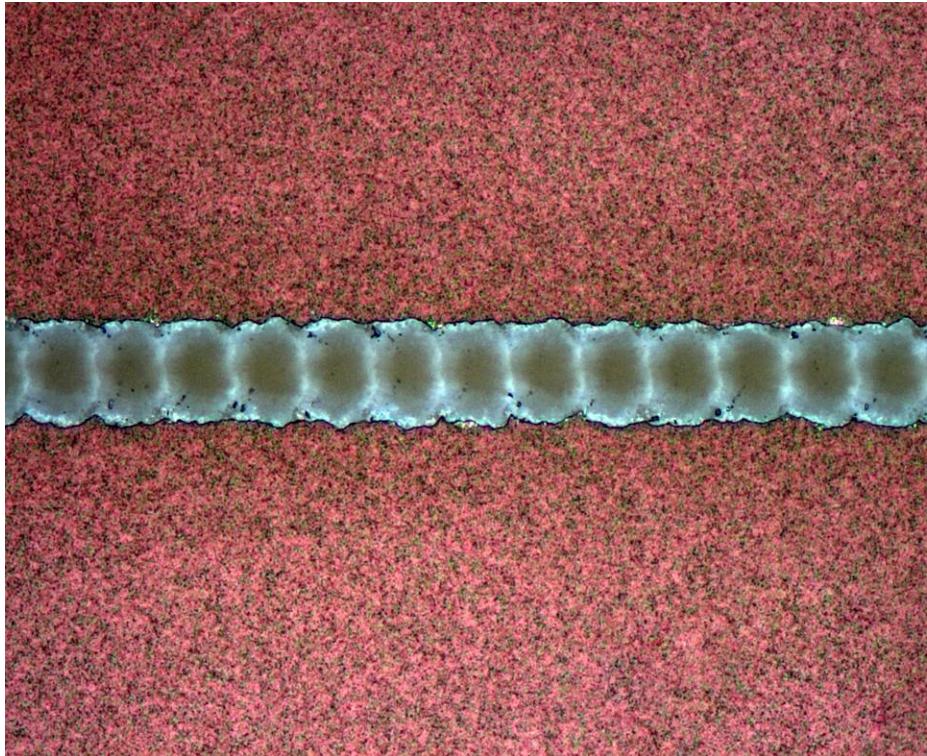
- Continuity of insulation scribes
- Penetration depth of insulation scribes
- Distribution and orientation of the crystals, tension and micro cracks in the crystalline silicon thin film

Important microscope accessory:

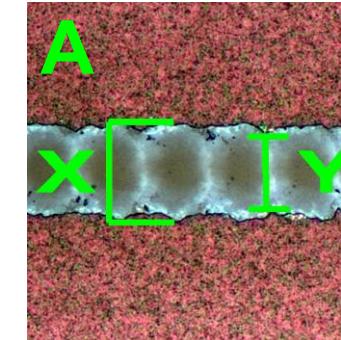
- Manual or motorized stage with glass insert
- Transmitted light module



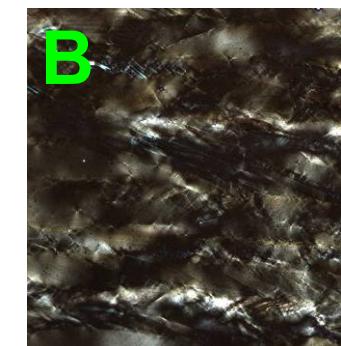
Thin Film Solar Cells



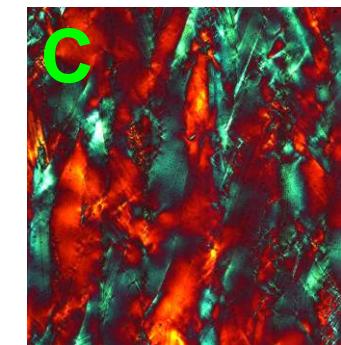
Thin Film Solar Cell
Reflected polarized light
EC Epiplan-NEOFLUAR 50x/0.80



CdTe Thin Film Solar Cell
Laser scribe on thin film solar cell in transparent electrode (TCO) layer on glass
EC Epiplan-NEOFLUAR 50x/0.80



Silicon Thin Film Solar Cell
Surface of a thin film silicon solar cell was acquired in reflected polarized light
EC Epiplan-APOCHROMAT 50x/0.95



Silicon Thin Film Solar Cell
Same as in B, but acquired in transmitted polarized light with lambda plate
EC Epiplan-APOCHROMAT 50x/0.95

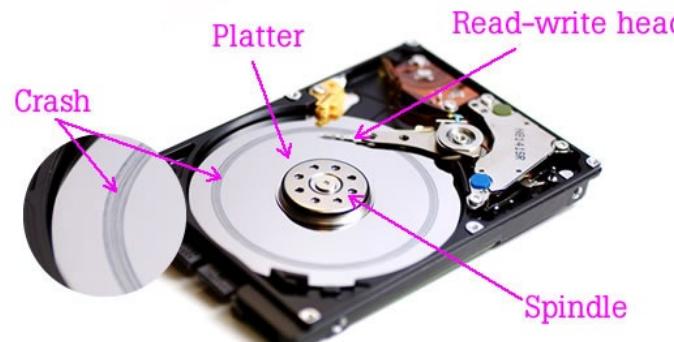
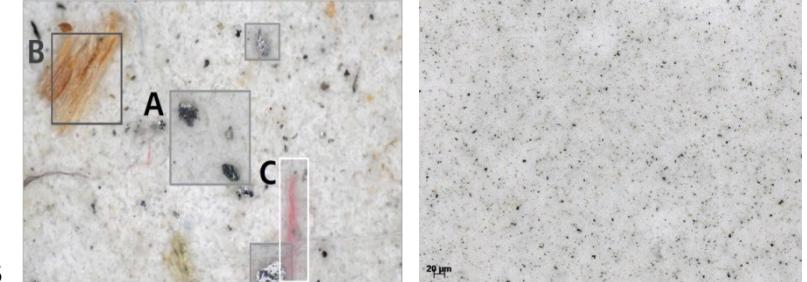
Technical Cleanliness Analysis (TCA)

Introduction



ZEN core Technical Cleanliness Analysis (TCA)

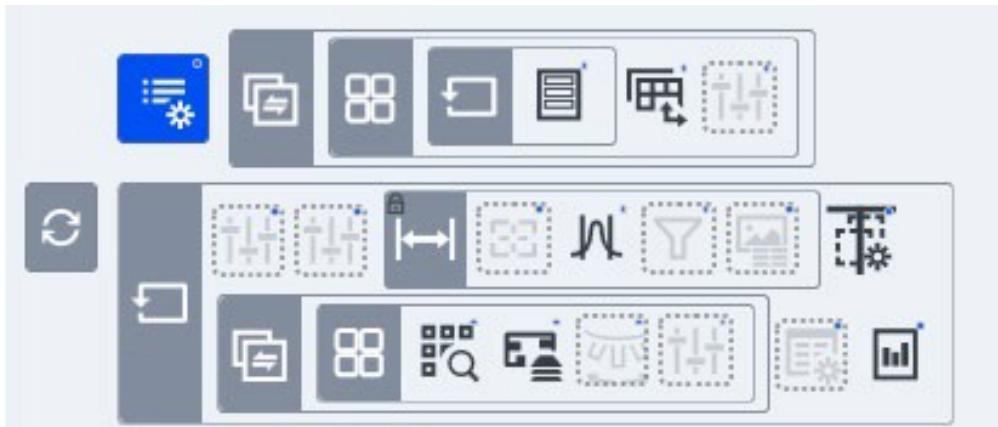
- Software module for **quality control**
- **Dedicated system solution** focused on **efficient** technical cleanliness analysis
- Cleanliness of **Component / oil** & **medical devices**



Contamination Analysis in Electronics Hard Disk Drive



TCA Workflows



Component Cleanliness

Supervisor

Fast and guided system configuration

Operator

Focus on result interpretation

ZEN core TCA Job Templates

- Component Cleanliness Testing
- Oil Cleanliness Testing

Acquisition, analysis, result interpretation, documentation

ZEN core Analyzer TCA Job Templates

- Component & Oil Cleanliness Testing

Loaded images (small demo images), analysis, result interpretation with approval definition, documentation

	Oil Cleanliness Testing	06.07.2020 03:03:54	Material Analysis
	Component Cleanliness Testing	06.07.2020 03:03:54	Material Analysis

Management of Standards (National, International and Company)



TCA Standards are managed in the [Standard Template Editor](#)

The screenshot shows a software interface for managing standard templates. The top navigation bar includes 'Show' (dropdown), 'Standards Technical Cleanliness' (selected), 'Filter Templates...', and a search icon. The main area has a header with columns: NAME, LAST ACCESS, and CATEGORY. On the left, there's a sidebar with categories: All, Technical Cleanliness Analysis (selected), Component Cleanliness, and Oil Analysis. The main list contains ten entries:

NAME	LAST ACCESS	CATEGORY
ISO 4407 (2002) ⓘ	7/20/2020 3:50:45 PM	Technical Cleanliness Analysis
ISO 16232 (2018) Extended Analysis ⓘ	7/20/2020 3:50:45 PM	Technical Cleanliness Analysis
ISO 16232 (2018) Standard Analysis ⓘ	7/20/2020 3:50:45 PM	Technical Cleanliness Analysis
VDI 2083, Blatt 21 (2019) Standard Analysis ⓘ	7/20/2020 3:50:45 PM	Technical Cleanliness Analysis
VDA 19.1 (2015) Standard Analysis ⓘ	7/20/2020 3:50:45 PM	Technical Cleanliness Analysis
NAS 1638 (2011) ⓘ	7/20/2020 3:50:45 PM	Technical Cleanliness Analysis
SAE AS4059 Revision F (2013) Table 2.1 ⓘ	7/20/2020 3:50:45 PM	Technical Cleanliness Analysis
VDA 19.1 (2015) Extended Analysis ⓘ	7/20/2020 3:50:45 PM	Technical Cleanliness Analysis
SAE AS4059 Revision F (2013) Table 1.1 ⓘ	7/20/2020 3:50:45 PM	Technical Cleanliness Analysis
ISO 4406 (2017) ⓘ	7/20/2020 3:50:45 PM	Technical Cleanliness Analysis

[Standard templates are linked to the job templates](#)

- direct export / import with job templates
- GxP compliance

[The Standard Template Editor supports our customers with need for individual company standards](#)

[Standard Template: in “Mange Templates”](#)

- Size classification for length and width
- Definition of acceptance criteria to identify potentially process critical particles
- Definition of cleanliness level

[TCA Standard Templates](#)

- Locked
- Cannot be modified
- Copied & Edited

Acceptance Criteria

Define Length Classes

Classes

Name	Color	Length [µm]		Allowed Number of Particles			Fiber
		Lower Limit	Upper Limit	Metallic-Shiny	Non-Shiny		
E	Green	50	100	100	550	10	---
F	Yellow	100	150	50	430	5	---
G	Orange	150	200	10	20	4	---
H	Purple	200	400	1	10	2	---
I	Blue	400	600	0	0	0	---

I. Definition by number of particles per size class (and type)

Define Approval Logic

Logic

FOR TYPE Metallic s... IF length X (µm) ≥ 100 AND width Y (µm) ≥ 20 Result NOK

OR

FOR TYPE Any IF width Y (µm) ≥ 50 Result NOK

OR

FOR TYPE Any IF length X (µm) ≥ 250 Result NOK

Add Class

II. Definition by particles size length / width

Appearance in the workflow

1. Standard Selection Tool
one or more standards are selectable

2. Result view

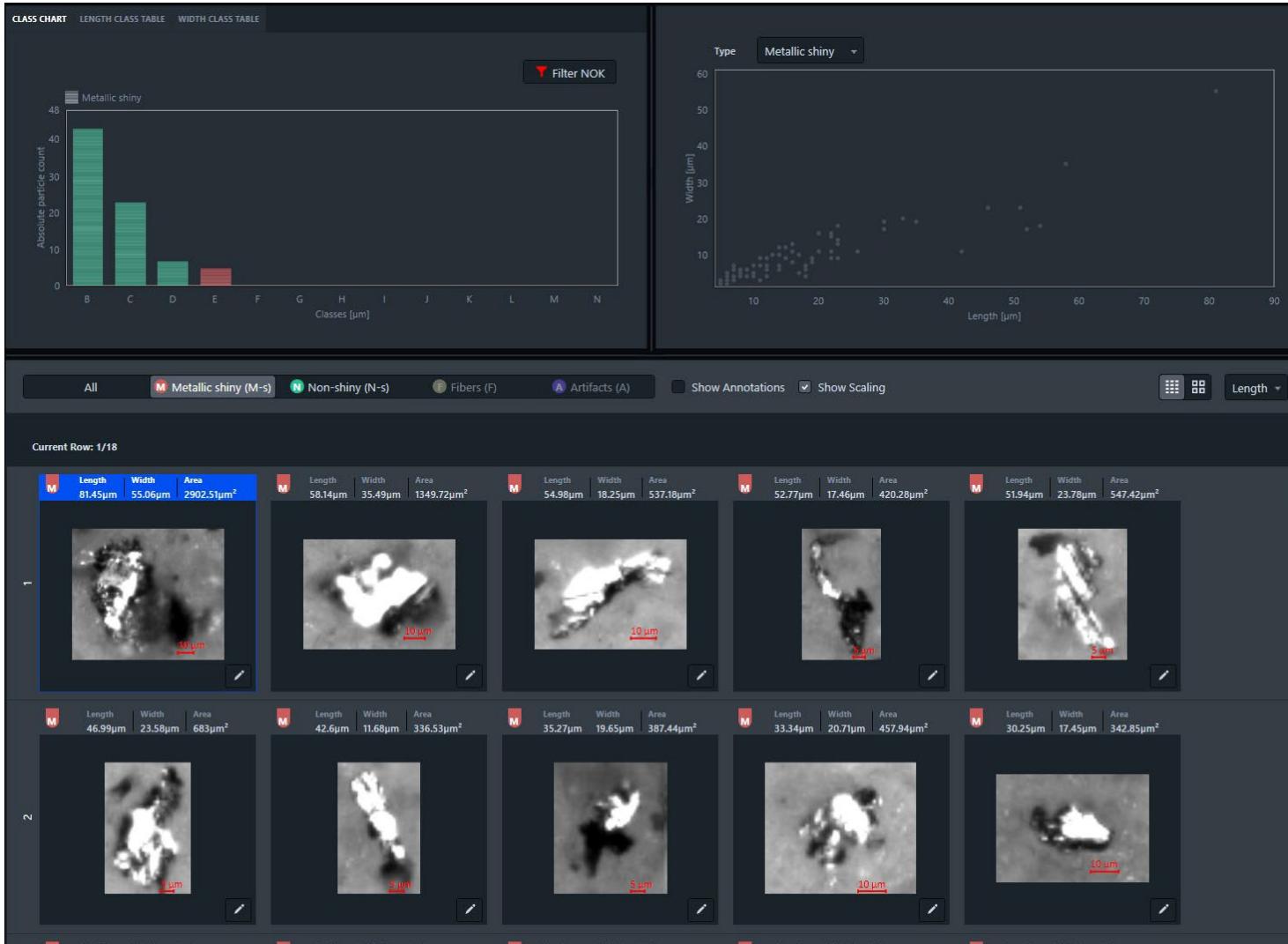
- Class tables (I)
- Class chart (I)
- Scatter plot (II)

3. Approval results (OK/NOK)
Based on acceptance criteria
Indicated by color signal
Filtering

Rapid identification of potential critical particles

➤ Time and cost savings

Size Distribution View



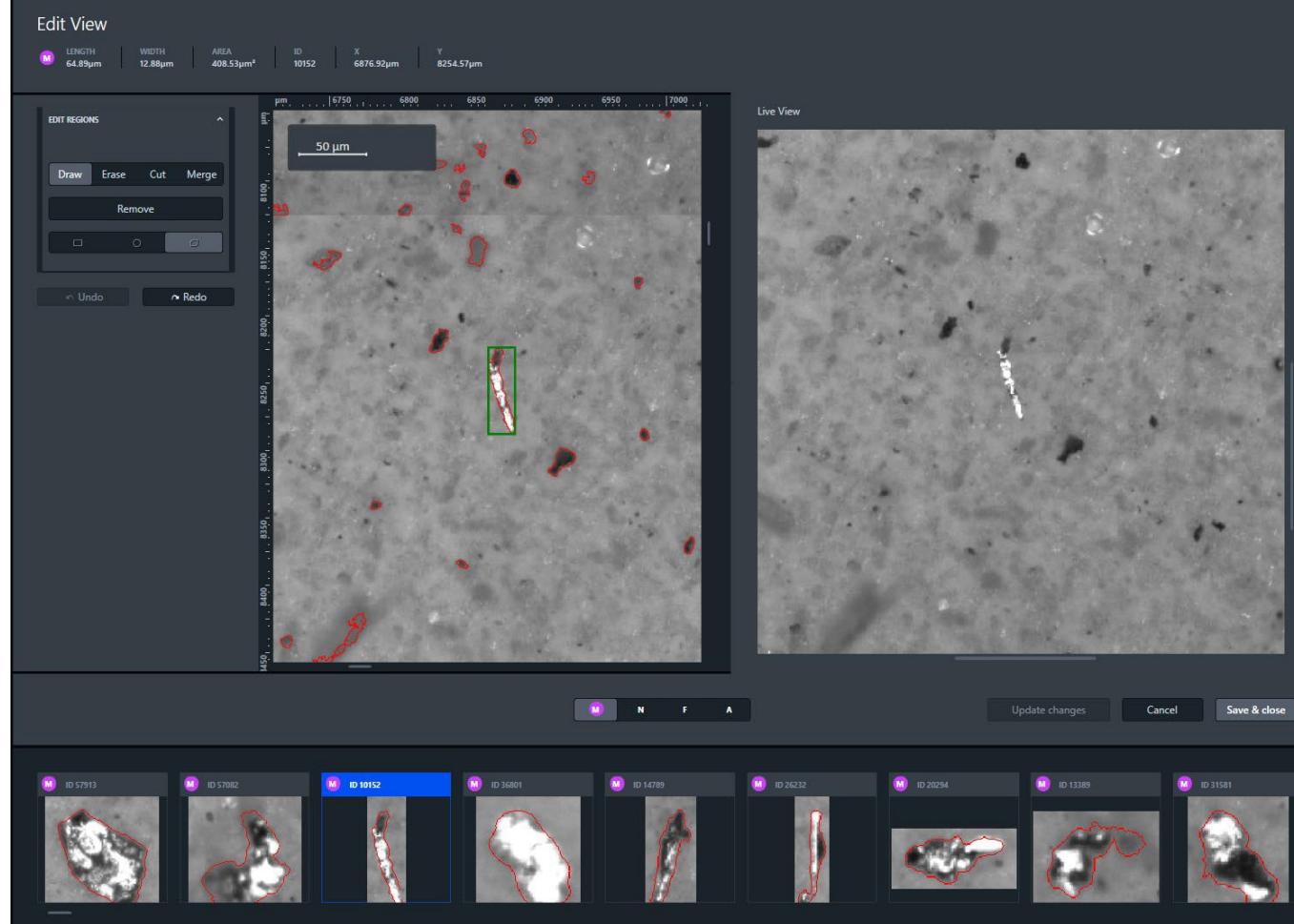
Rapid Particle Inspection for Routine

- approval related particle inspection and interaction
- particle-based visualization of the measurement results
- fast inspection and revision of particles
- Scatter plot with **Product Finger Print**

Classification Parameter: Feret Maximum [μm]

Particle Length	Class 1 ($2 \leq X < \infty$)	Class 2 ($5 \leq X < \infty$)	Class 3 ($15 \leq X < \infty$)	Class 4 ($25 \leq X < \infty$)
All without fibers				
Normalized count per 100 ml (V)	644	644	144	64
Cleanliness level V	10	10	8	6
Approval	OK	NOK	NOK	NOK
Particle (Oil)				
Normalized count per 100 ml (V)	644	644	144	64
Cleanliness level V	10	10	8	6
Approval	OK	NOK	NOK	NOK
Fiber				
Normalized count per 100 ml (V)	4	4	4	4
Cleanliness level V	2	2	2	2

Particle Revision View

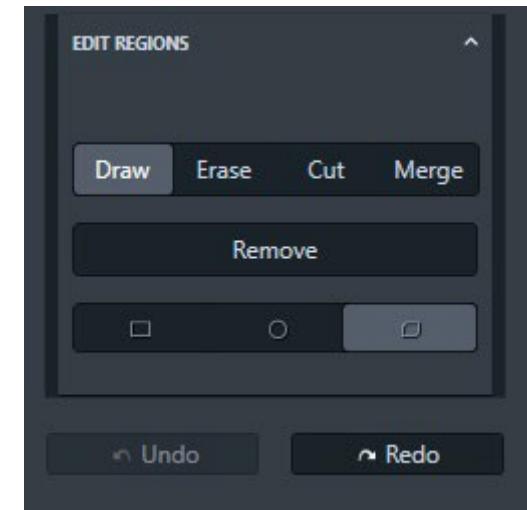


Comfortable Particle Revision for Routine

- Particle Gallery for rapid particle retrieval in live view
- Particle Revision: separating, combining, editing of particles, particle type change

Typical use cases:

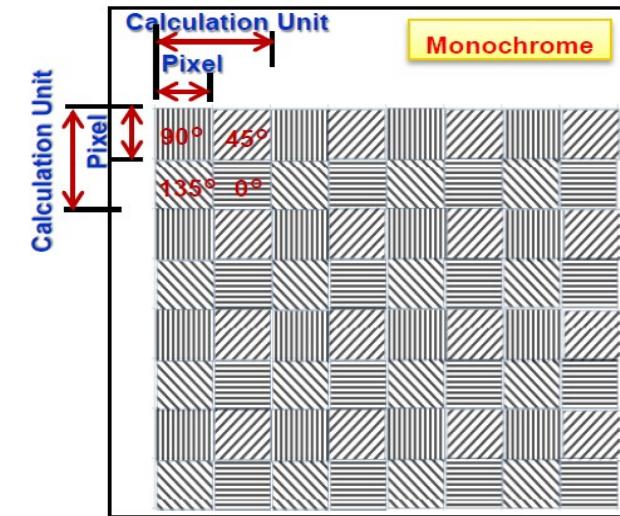
- Merging of fiber fragments
- Separation of particles lying close together



Main improvements

- One specimen scan instead of two
- No shift correction (BF/POL) needed
- Single shading correction
- Halving of the time required for image acquisition in ZEN core

On-chip polarization technology
(patented by Sony)



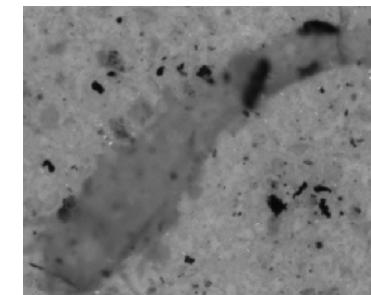
Particle Type Differentiation



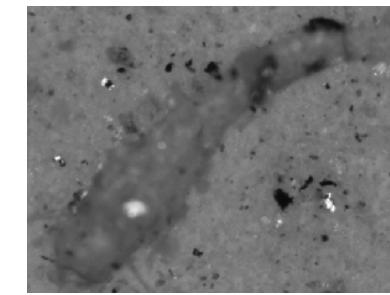
Metallic particle – 90° POL



Metallic particle – 135° POL



Non Metallic particle – 90° POL



Non Metallic particle – 135° POL

ZEISS patent submitted

Technical Cleanliness Workflow with on-chip polarization technology

Correlative Microscopy

Benefits of Correlative Microscopy

ZEN connect

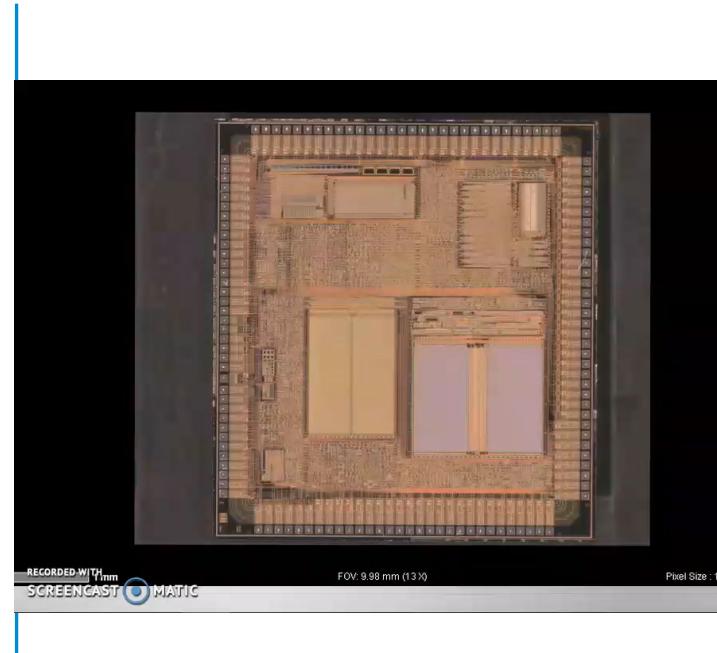


Open Software Platform

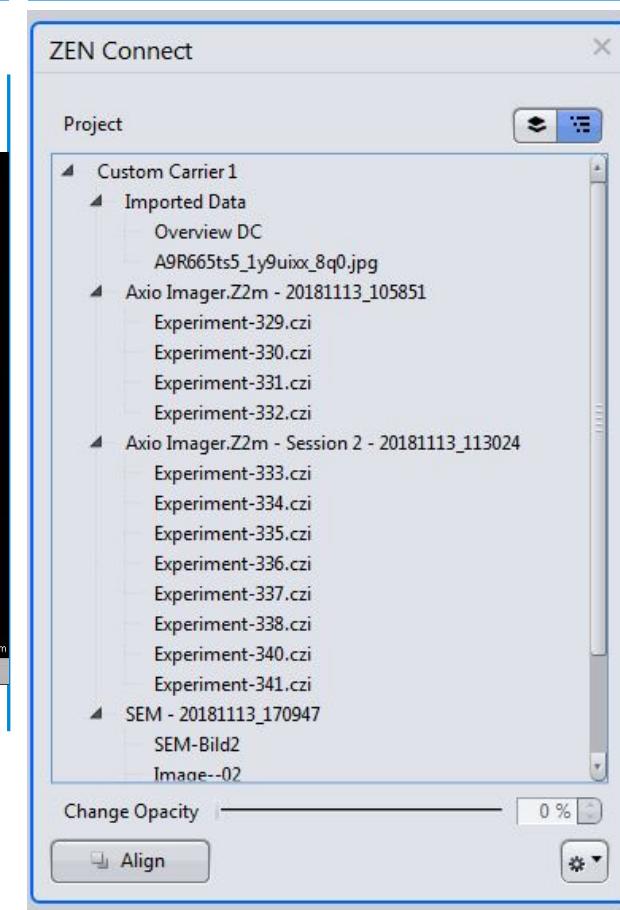


BIO-FORMATS

Easy Navigation + Scientific Context of Multiscale/ Multimodal Imaging



Smart Data Management

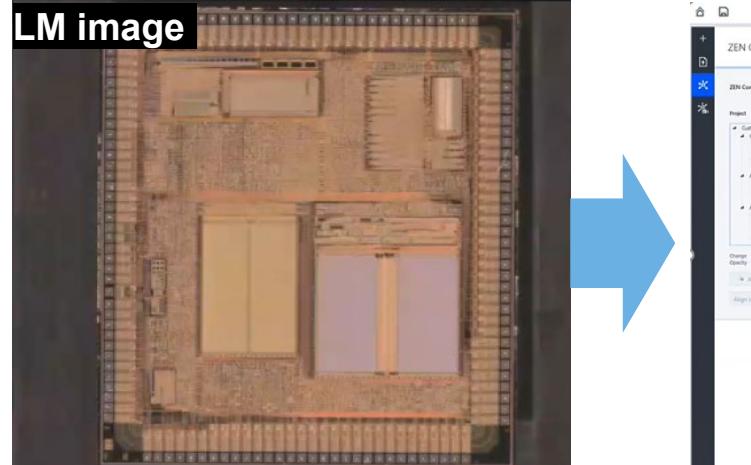


Workflow - Driving to Region of Interest (ROI)

Zen Connect



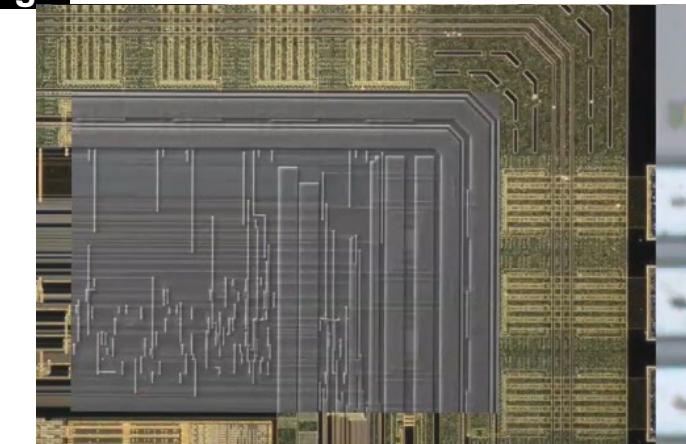
1. Acquire large FOV with
1st imaging system



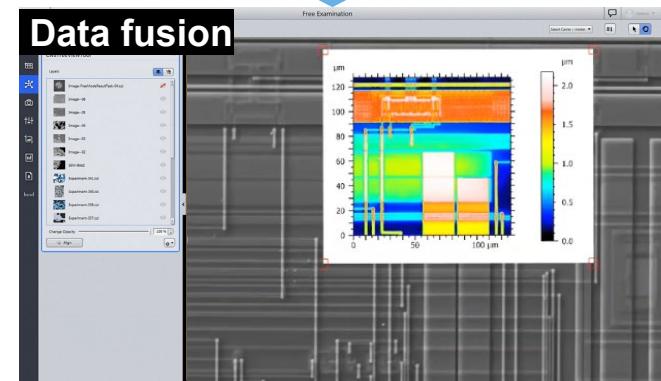
2. Organize acquired datasets
into a project



3. Align data with 2nd ZEISS MOTORISED
system. Move to ROI & take more images
SEM image

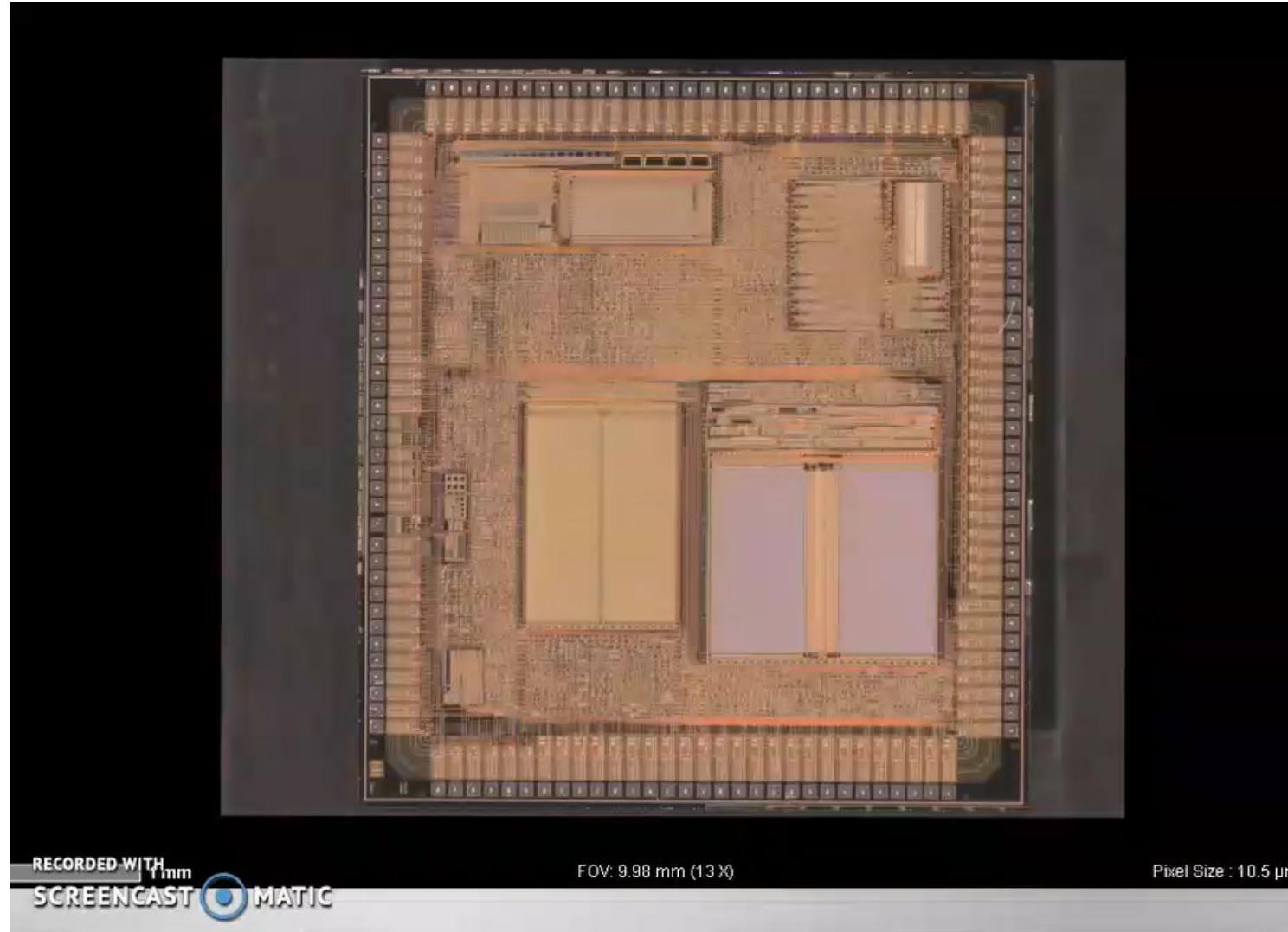


4. Bring your Data into context



Semiconductor (Integrated Circuit)

Zen Connect Easy Navigation (Google Earth-like) + Multi-modalities
(Axio Imager - LSM 900 MAT - EVO 15)



- Overview image with Light Microscope at low magnification
- View in various Contrast methods with Light microscope
- Switch to Confocal LSM for 3D height map measurements, roughness, etc.
- Switch to SEM and perform high resolution imaging

Smart Data Management



- When and on which system did I take the images?

Project Tree

Sessions

Show/Hide in Layer View

The screenshot shows three windows of the ZEN Connect software:

- Project Tree:** Shows a hierarchical list of projects and sessions. Projects include "Custom Carrier 1", "Imported Data", "Axio Imager.Z2m - 20181113_105851", "Axio Imager.Z2m - Session 2 - 20181113_113024", and "SEM - 20181113_170947". Sessions list various experiments and images.
- Sessions:** Shows a list of sessions with their respective experiment files.
- Show/Hide in Layer View:** Shows a list of layers (Image--06, Image--05, Image--04, Image--03, Image--02, SEM-Bild2, Experiment-341.czi, Experiment-340.czi, Experiment-338.czi, Experiment-340.czi, Experiment-341.czi) with checkboxes for visibility and transparency controls.

Complete Project Storage in Job Results

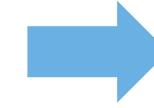
Result Jobs			
Name	Created	Last Modified	
FreeMode	23.01.2018 20:07:30	23.01.2018 20:07:30	
Steel Ca treatment	20.11.2018 13:43:08	20.11.2018 17:38:13	
181113_Connect_Demo_Materials_Research	13.11.2018 17:09:47	13.11.2018 17:40:13	
181113_AM_QAQC_Demo_Connect	16.11.2018 12:54:18	16.11.2018 13:42:05	
Battery	30.11.2018 13:51:36	30.11.2018 14:53:16	
Battery2Raman	18.12.2018 14:29:16	16.01.2019 13:27:00	
Session test	10.01.2019 11:46:14	10.01.2019 11:59:56	

Applications

Integrated Circuit

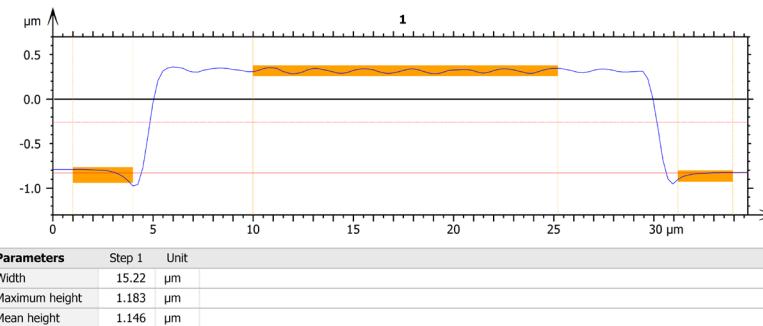


Light/ Confocal Microscope

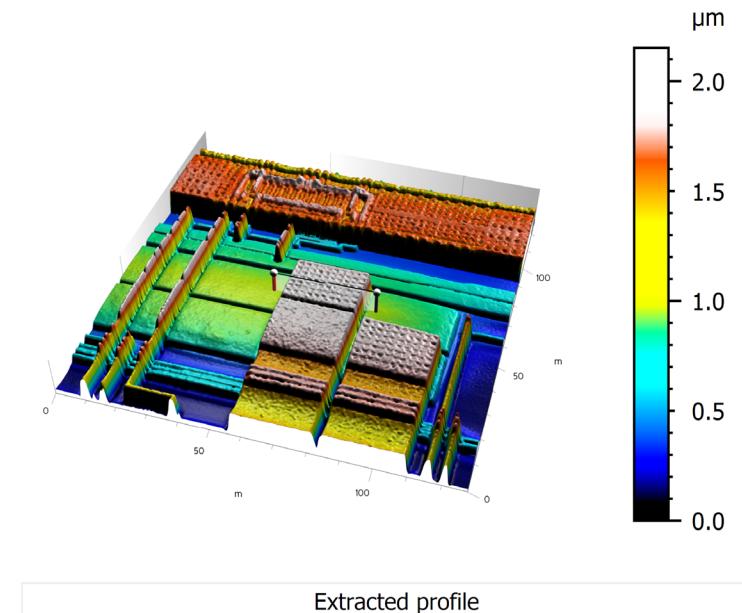


Electron Microscope

- **Light Microscope** for multi-contrast imaging (BF, DF, CDIC, POL, FL)
- **Integrated Confocal pinhole laser** scanning for **high z-resolution**, & 3D topography **height map**
- Post-analysis **Conformap** software allows freely selectable step height, width measurements of circuits
 - **Dimensional analysis/ Step height** measurements
 - **Non-contact roughness** measurements
- **High x-y resolution** imaging in **EM**



ISO 4287			
Amplitude parameters - Roughness profile			
Rz	0.3579	μm	Gaussian filter, 0.008 mm
Ra	0.0575	μm	Gaussian filter, 0.008 mm
Rsk	-0.9133		Gaussian filter, 0.008 mm



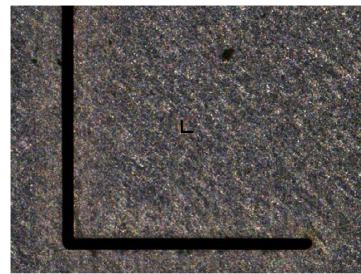
ZEN Connect 2D Add-on (Shuttle & Find)

Precise Relocation between light microscopy and electron microscopy



LM

Fast Calibration

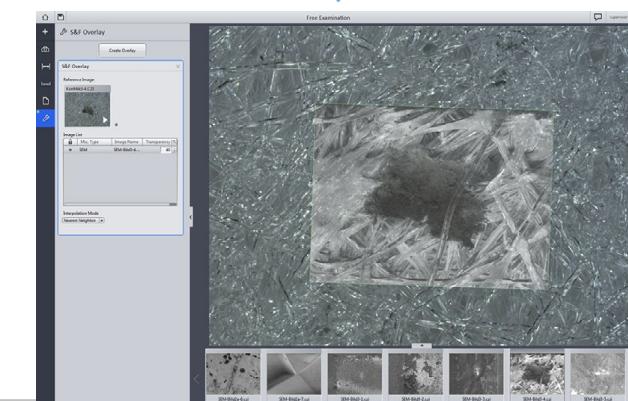
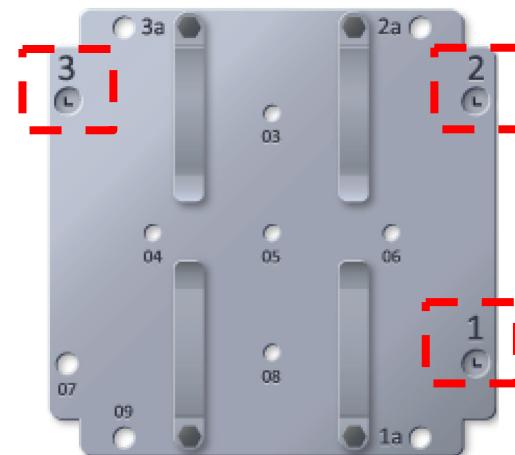


Saved
ROIs



EM

Fast Calibration & Rapid Relocate



Shuttle & Find

Key Features



Fast Calibration

Semi-automatic 3-point calibration

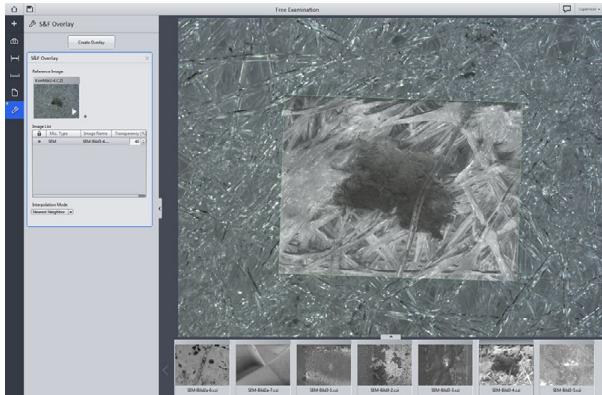
Precise Correlation

Create correlative image overlays



Relocation accuracy

<-25 µm (coarse); <-10 µm (fine) – depending on stages



Fully Integrated into ZEN core

Interpolation Mode: Nearest Neighbor

Sift parameters:

- Detection Method: Harris Laplace
- Descriptor Type: SIFT Signless
- Selector Type: RANSAC
- Registration Method: Translation + Rotation + Iso S...
- Matching Threshold: 1.50

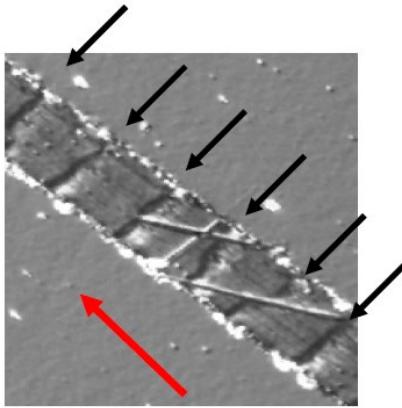
C-DIC (Circular Differential Interference Contrast)

C-DIC vs DIC

Unique Features

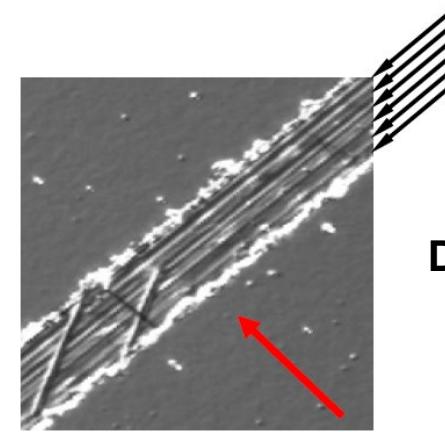
Visibility of Orthogonal Phase Structures in DIC versus CDIC

DIC

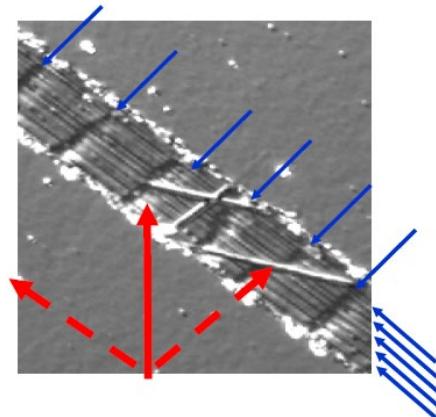


DIC: Orthogonal structures (↗) will always appear **sequentially** and after the stage has been rotated 90°. With C- DIC the prism is rotated

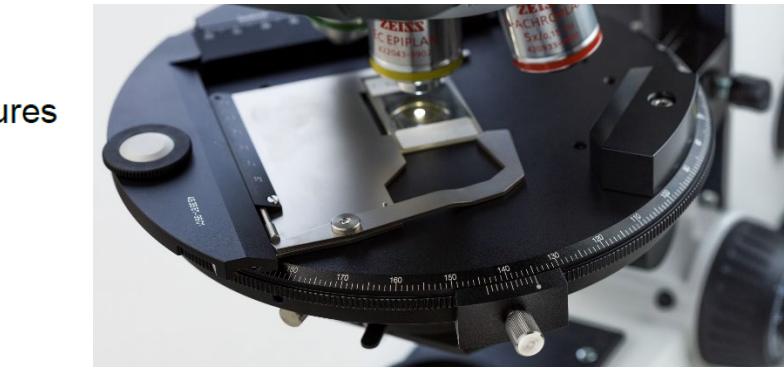
DIC



C-DIC



CDIC: Orthogonal elements (↙) appear **simultaneously** after the prism shear is rotated 45° against the orientation of both perpendicular structures



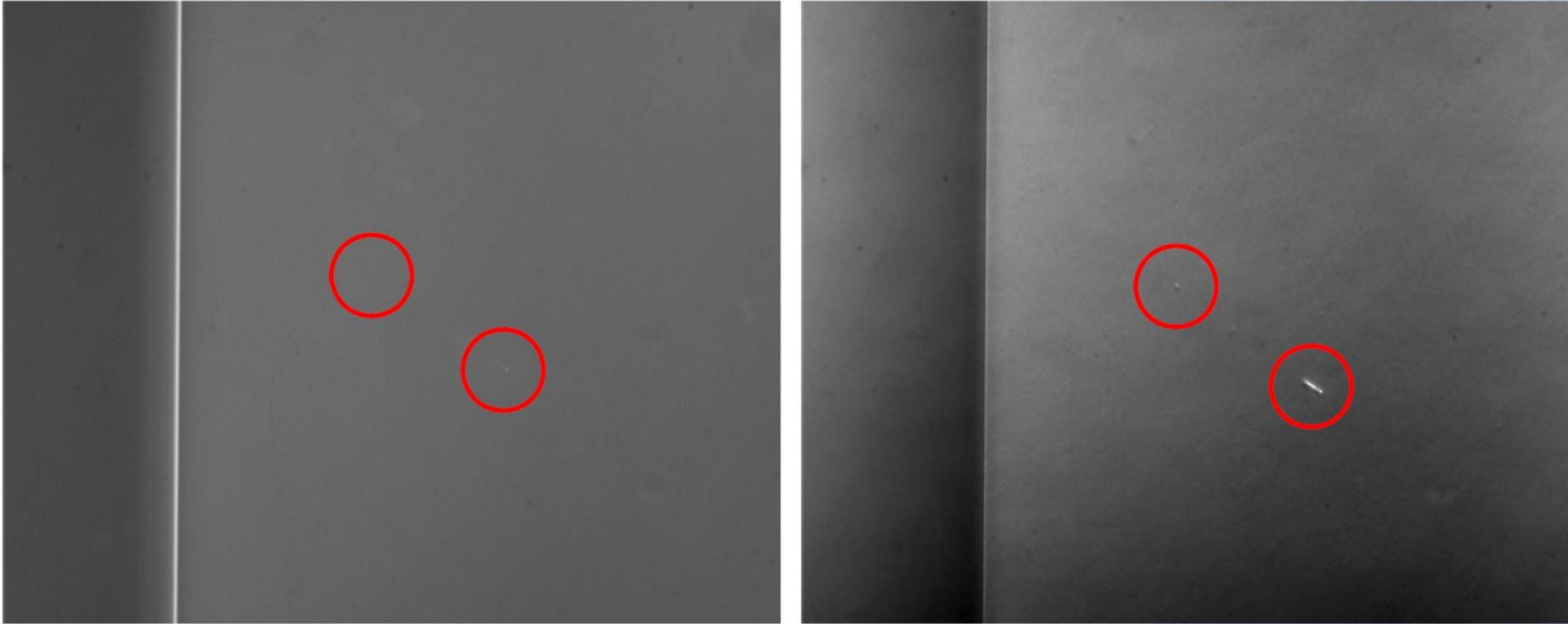
Rotatable sample stage of DIC is obsolete !

C-DIC (Reflected Light) Components



- **C-DIC reflector module**
- **C-DIC prism** may be either a **simple slider type** with knob for prism rotation or a **turret type (motorized/manual)**
 - **C-DIC prism slider** can be rotated azimuthally using large knurled ring for rotation of shear direction
 - **Image contrast/resolution** is varied using **knurled adjusting screw** (change to phase difference) by moving (sliding) prism perpendicular to optical axis

C-DIC (Reflected Light) Application Examples

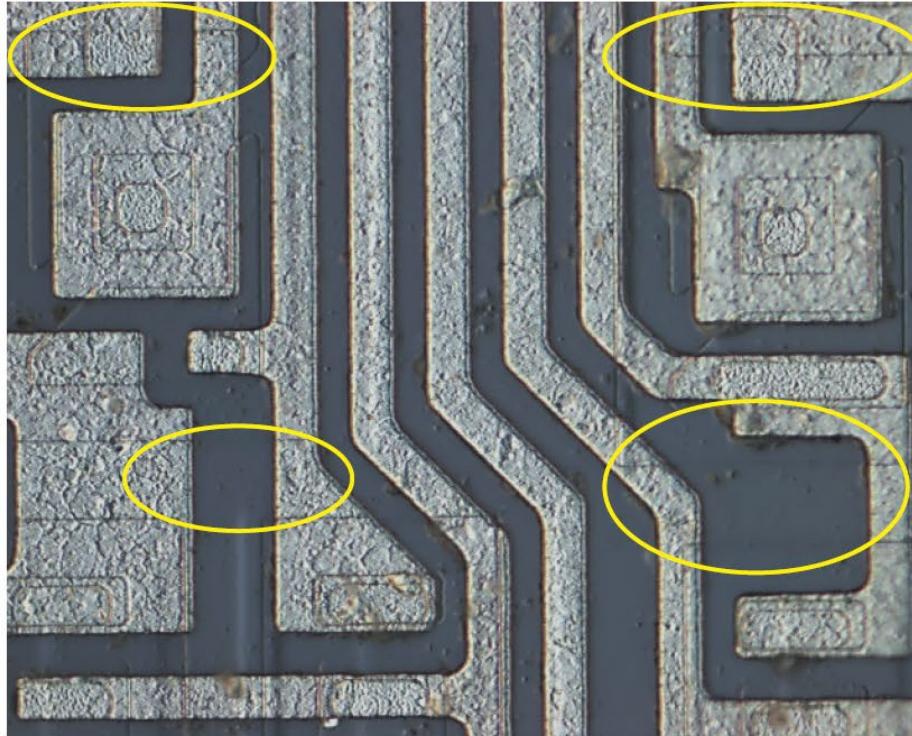


DIC

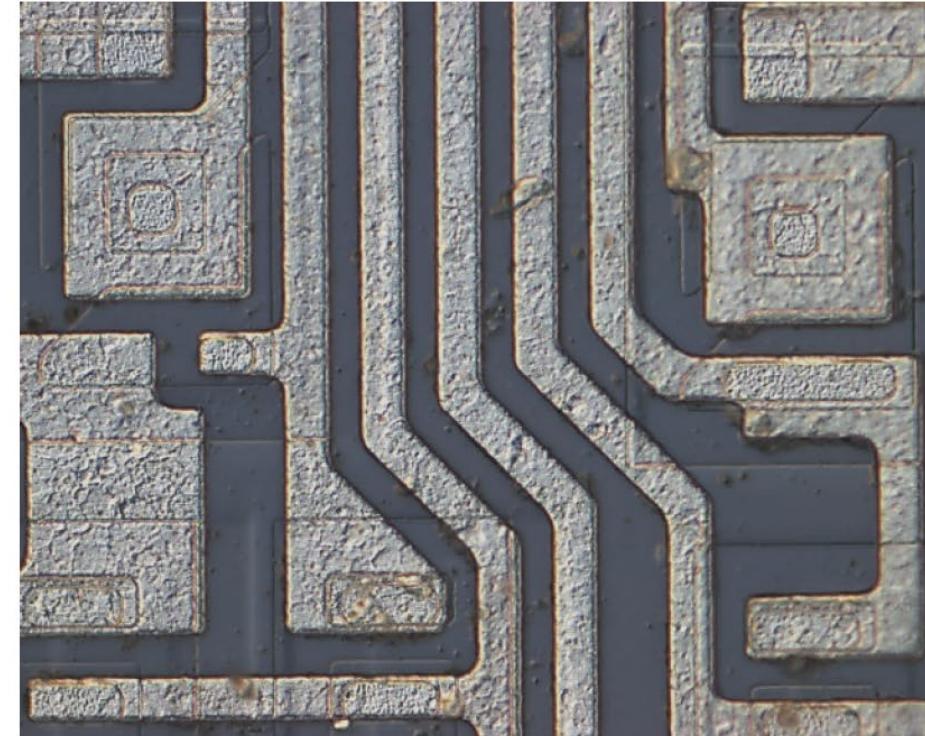
C-DIC

- LD EC Epiplan- NEOFLUAR 50x/0,55
- Minute contamination particles detected by C-DIC prism shear rotation

C-DIC (Reflected Light) Application Examples



Reflected Light DIC

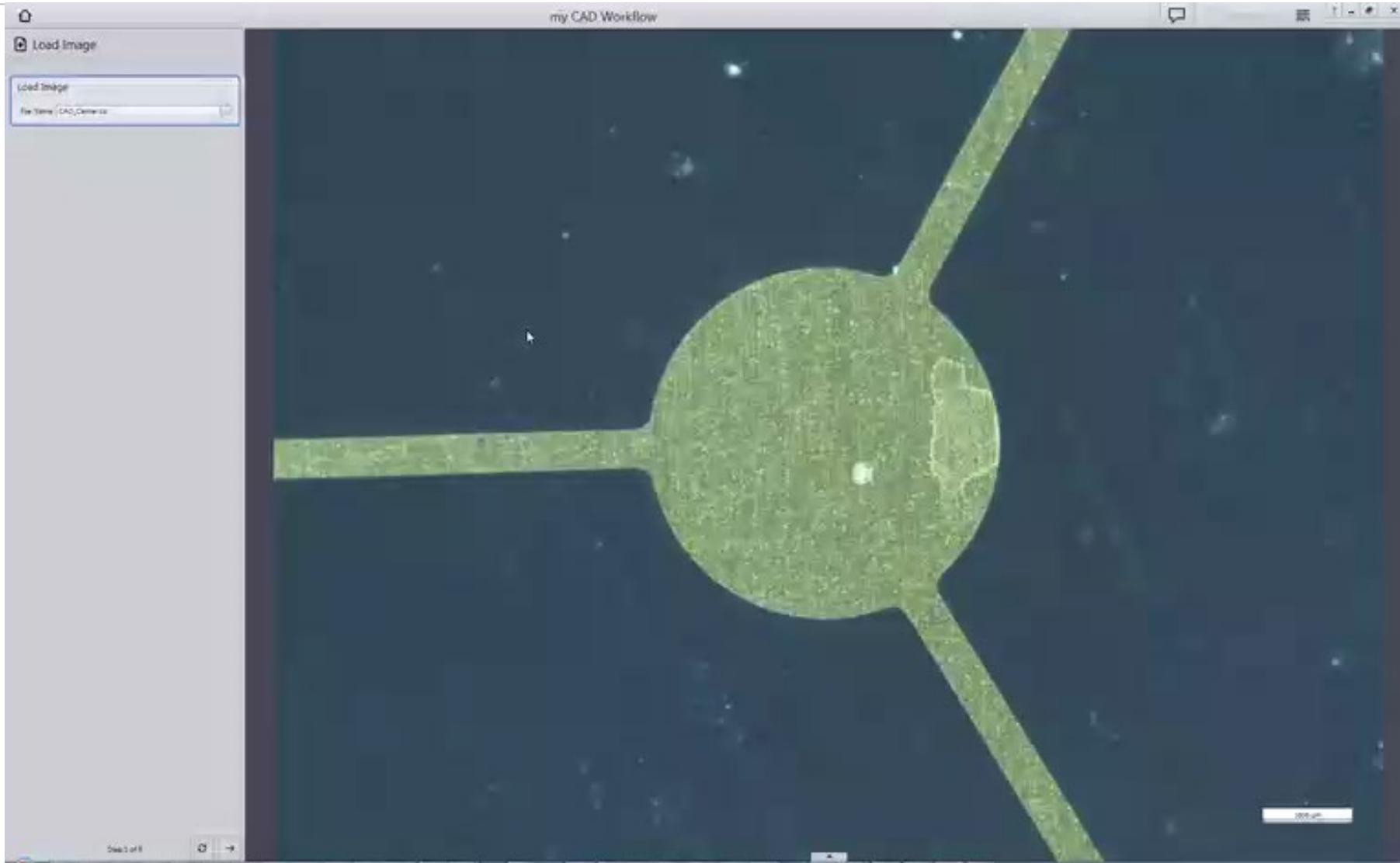


Reflected Light C-DIC

- Semiconductor integrated circuit / 50x objective
- Missing information in DIC image (yellow circled areas)

ZEN core CAD

ZEN core Module (CAD Overlay)



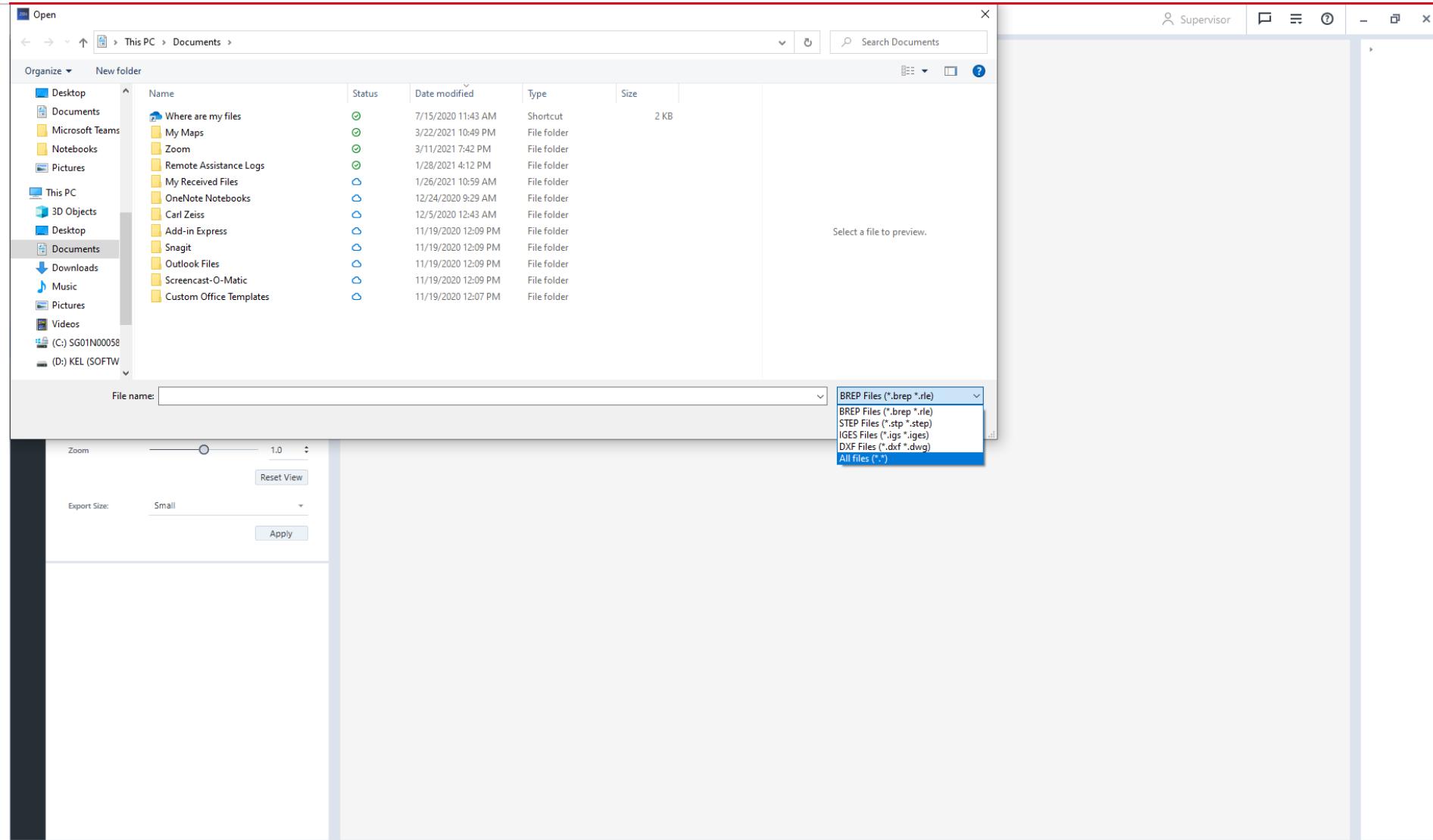
2D overlay CAD (computer aided design) files with ZEN core images

- Following CAD files are supported: ***.dxf, *.dwg, *.igs, *.iges, *.rle, *.stp, *.step, *.brp**

Example Workflow:

- Load/Acquire Image
- CAD Import
- CAD Overlay
- Interactive Measurement

Supported CAD Formats



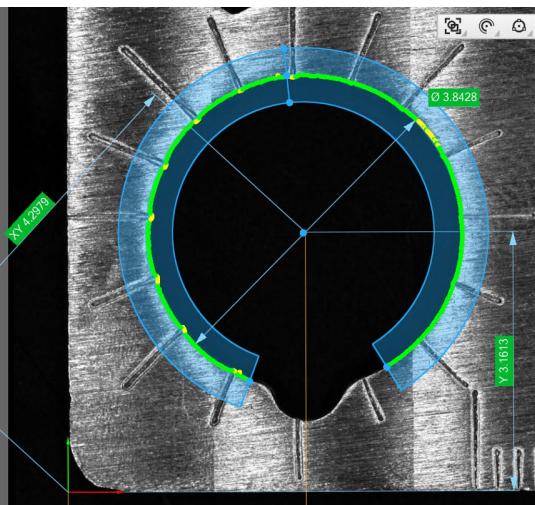
ZAPHIRE

ZAPHIRE

Automated Dimensional Metrology of Repetitive Parts

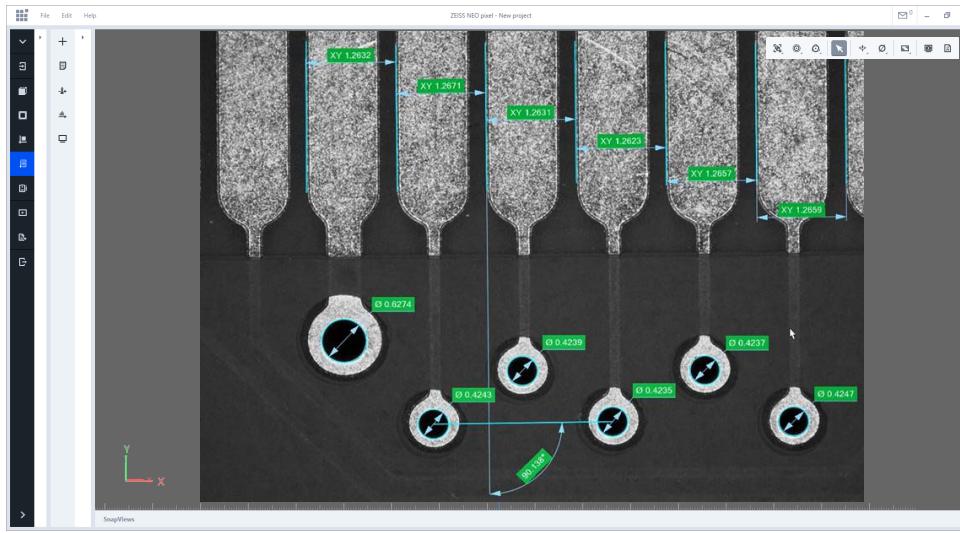


- **Snap an image in ZEN core & send to ZAPHIRE**
- Automated edge detection (**Search Zone**)
- User-independent results
- Automated measurements in **few seconds**
- **Automated Reporting** with Zeiss PiWeb
- **Trend Analysis & Statistics**

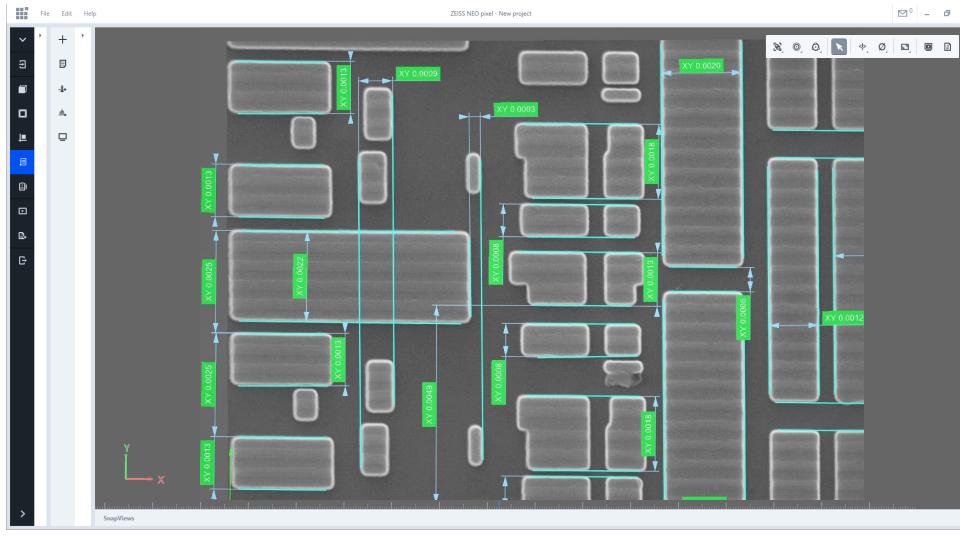


Application Examples

Electronics



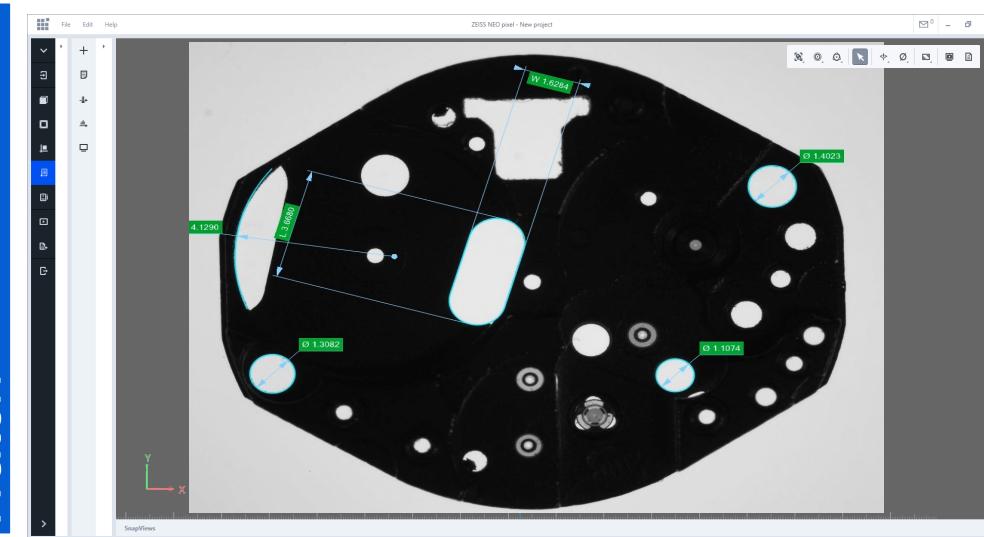
Semiconductor



Machining

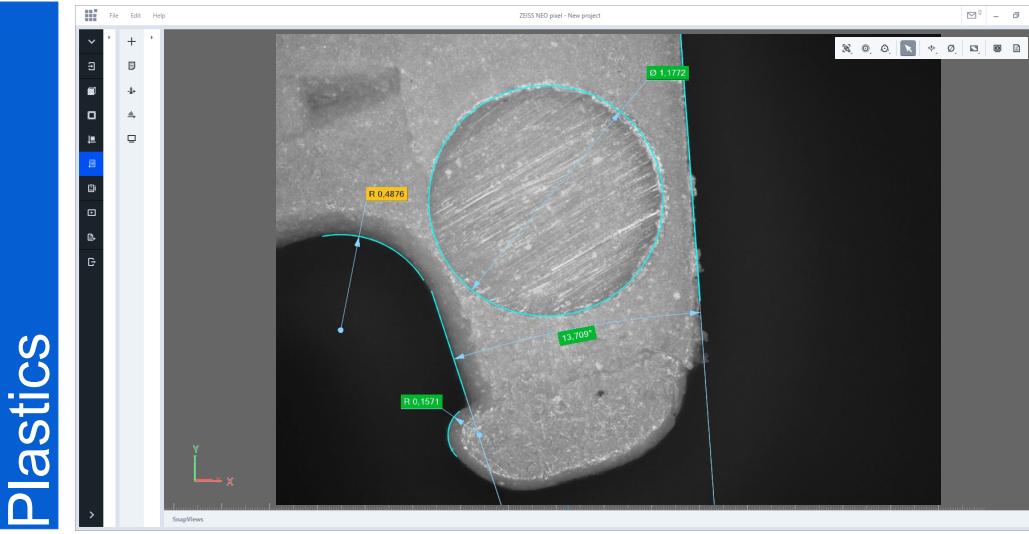


Watch

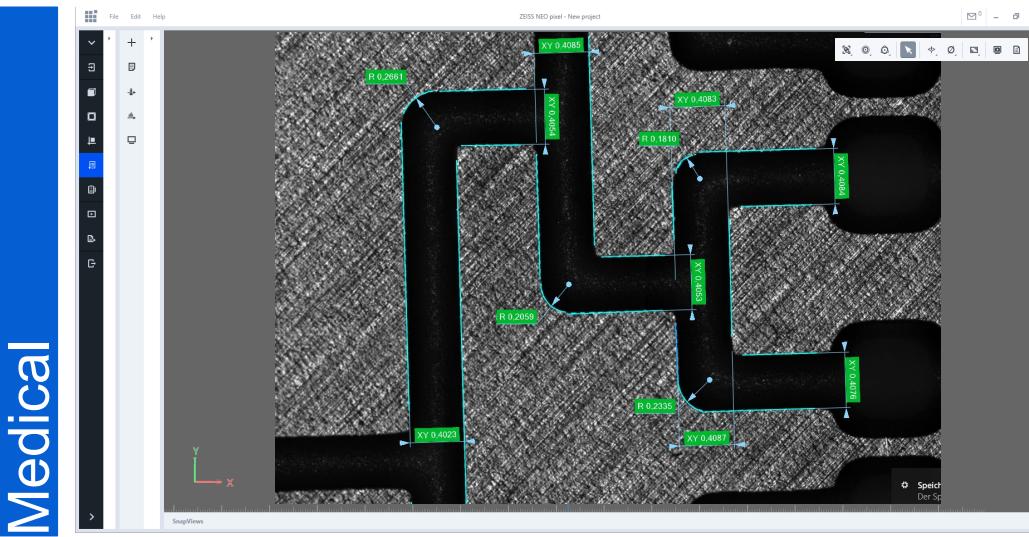


Application Examples

Plastics



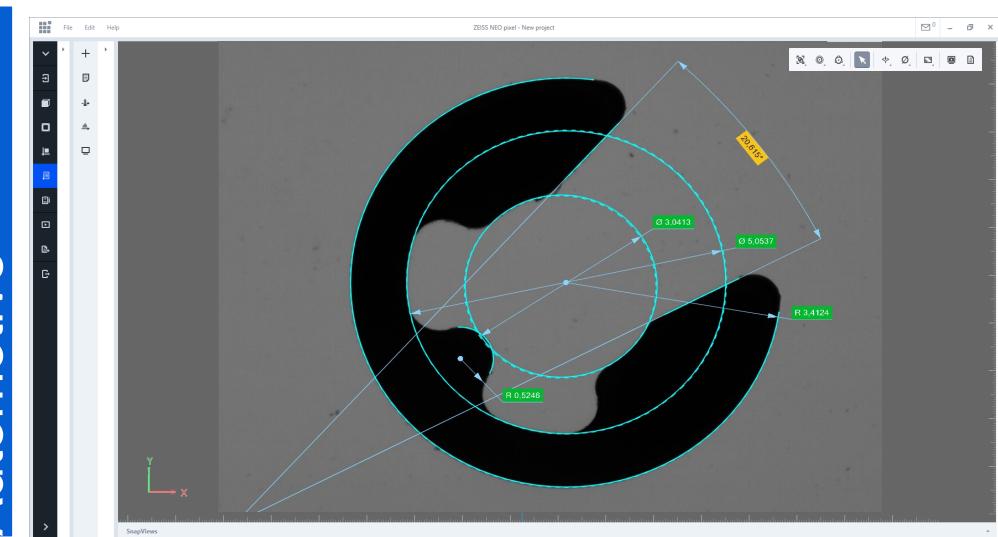
Medical



Filter

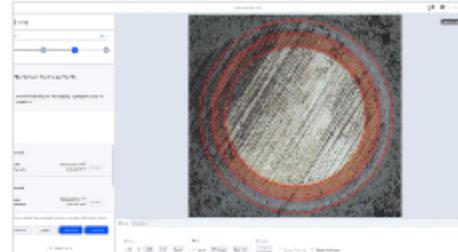


Automotive



Solutions Lab

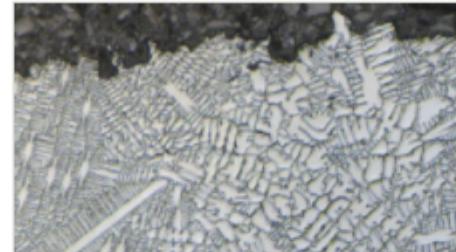
Solutions Lab



ZEISS Calotte Grinding Workflow

From the SolutionsLab for Coatings, Films & Surfaces

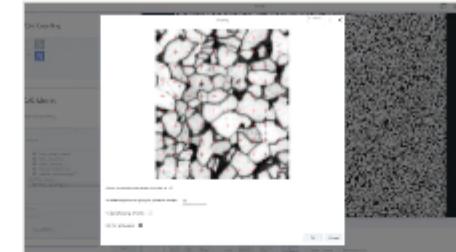
Determine the wear resistance of films and surfaces.



ZEISS Dendrite Arm Spacing Workflow

From the SolutionsLab for Measuring Dendrite Arms Using Light Microscopy

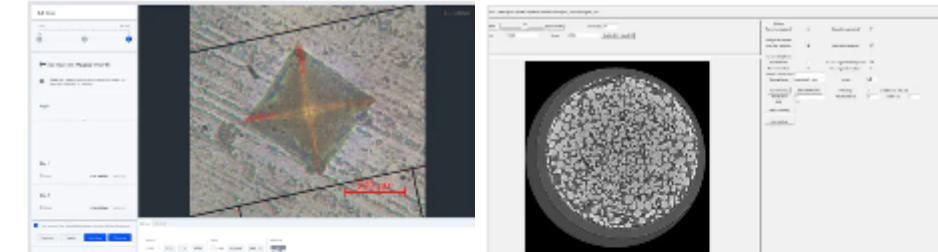
Combined automation through image processing and the ability for manual fine-tuning.



ZEISS Point Counting Workflow

From the SolutionsLab for light microscopy

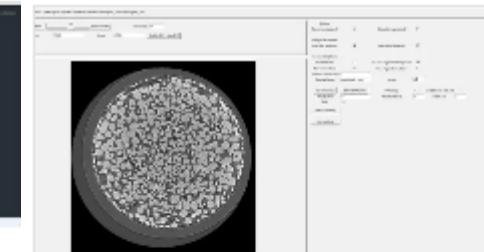
Determine the estimated volume fraction of a certain constituent or phase of interest in a sample.



ZEISS Microhardness Workflow

From the SolutionsLab for Metals

The Microhardness Workflow enables metallurgical testing to determine the hardness of a metal.



ZEISS Additive Manufacturing Powder Analyzer

From the SolutionsLab for Metals Part Production

Entire 3D volumes to be taken from raw data to fully analyzed results in a single click.

<https://www.zeiss.com/microscopy/int/products/microscope-software/solutions-lab.html>



Seeing beyond