EPFL GenISys Advancing the Standard

Automated SEM Metrology with InSPEC

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Presented by Zdenek Benes

EPFL

EPFL campus
CMi cleanroom

Historical Milestones

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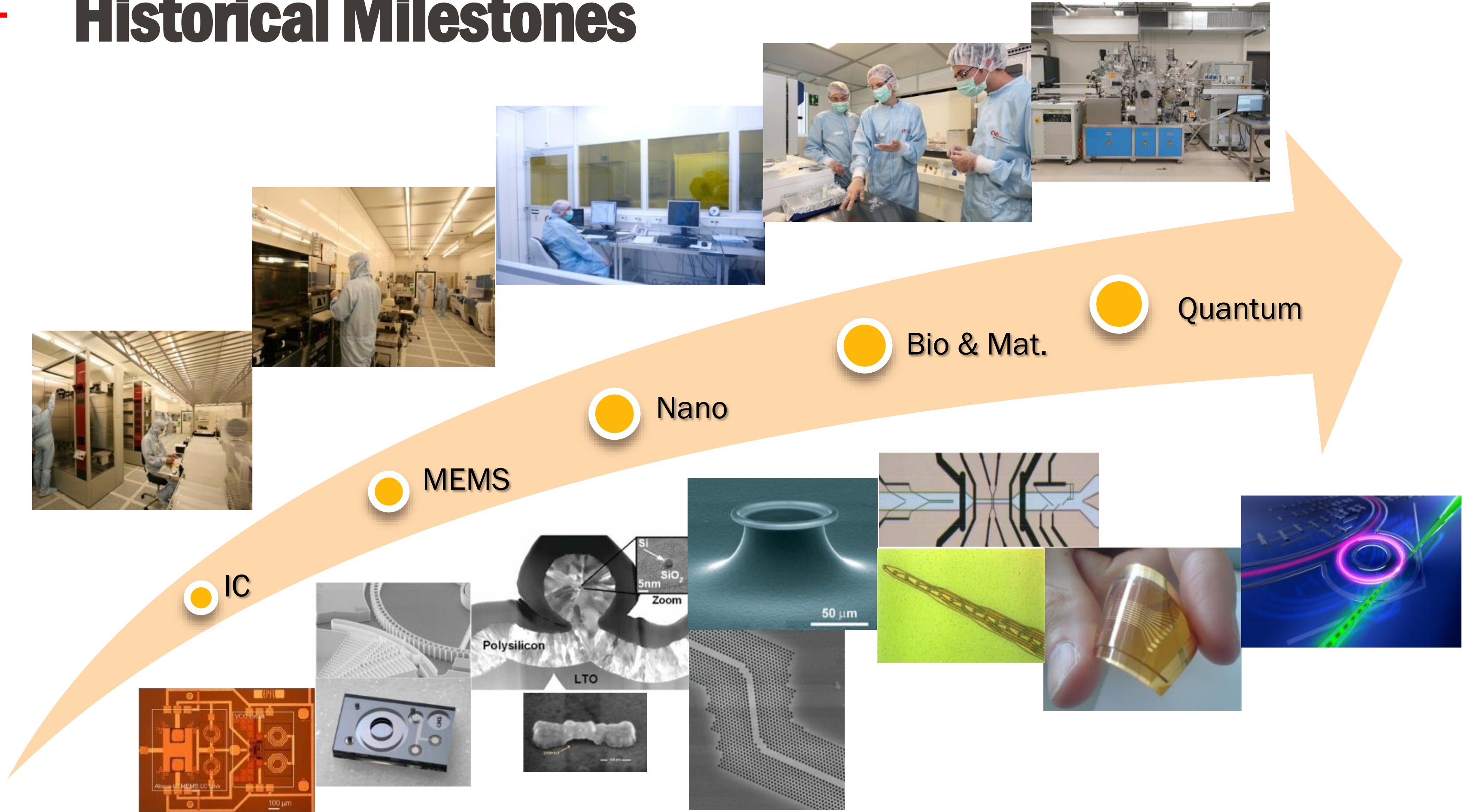
Milestone	Details
Microelectronics & MEMS 1998	• CMi created in 1998 & Cleanroom opened in March 1999 • Basic Microelectronics processes • MEMS processes like **Deep silicon etching**, **SU-8**
Nano / Electron Beam Lithography 2005	• **Electron Beam Lithography** ordered in december in 2005 • Focused Ion Beam ordered in september 2003 • Atomic Layer Deposition in 2011
Cleanroom extension 24/7 2010	• Cleanroom extension opened in 2010 for **more flexibility** and cheaper access • **Operated now in 24/7 mode** since 2012 • **PDMS**, SU-8, Chemistry, Metrology, Non-conventional processes
Materials Diversity 2013	• **Ion Beam Etching**, PVD, ALD, PLD, Dry Etching • Chemistry • Photolithography: Mask Fabrication, Coater & Developer, Mask Aligner
DUV Stepper lithography 2019	• **DUV stepper** • Renewal of aging tools & Adding new capabilities • Envision the acquisition of a second EBEAM at the horizon of 2022
Renewal & Broadening 2019	• Deep Si etcher - XeF2 etcher - CMP - Post CMP Cleaner - Super Critical Dryer - Metal etcher • **PVD Cluster** - LPCVD furnaces - PECVD - Flash Lamp Annealing - Direct Writer • **Wafer bonding** - CVD diamond - Optical Profiler - SEM - Ellipsometer
Quantum Science & Engineering 2022	• UHV evaporator (2x) for **Josephson Junctions** - UHV sputter for **Josephson Junctions** - ALD for SC • Second electron beam lithography system • **Cleanroom extension in 2025**

Historical Milestones



- Broadening the CMi offer and the CMi users base along the time

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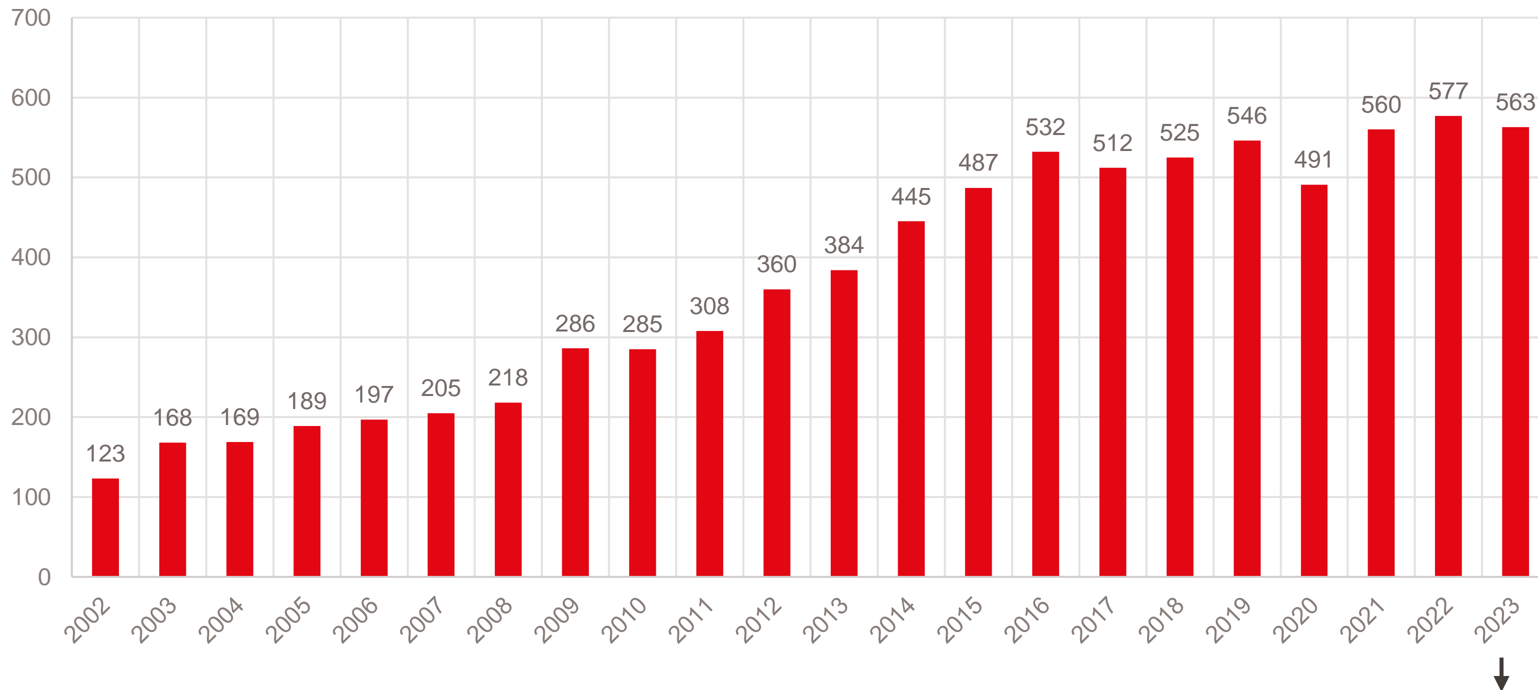
Users in 2023



- Evolution of the number of users over the years since 2002
- From 100 to 600 users

In 2023: 563 users belonging to 184 laboratories or compagnies

Metrology needs

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USERS

Process development
Process monitoring and control
Dispositioning of final products

CLEANROOM STAFF

Process development
Process monitoring and control

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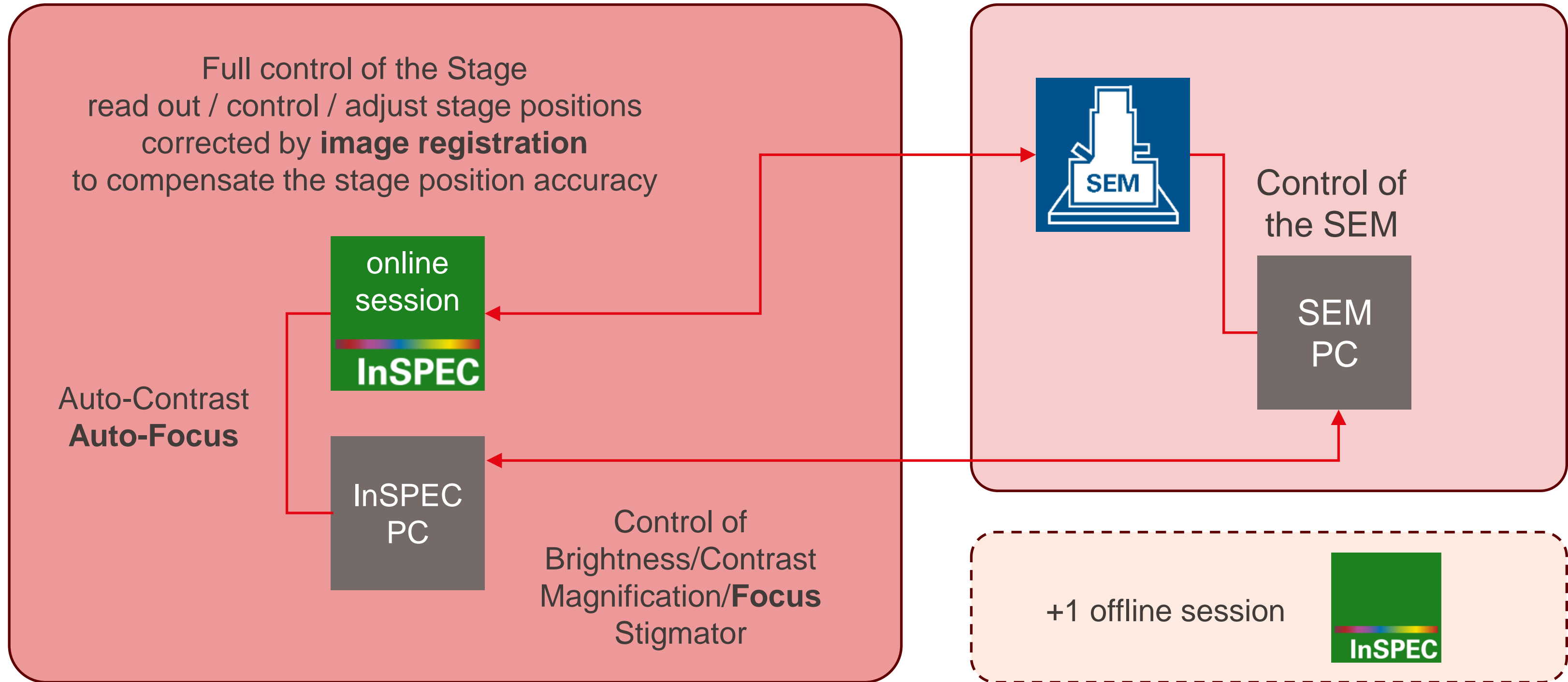
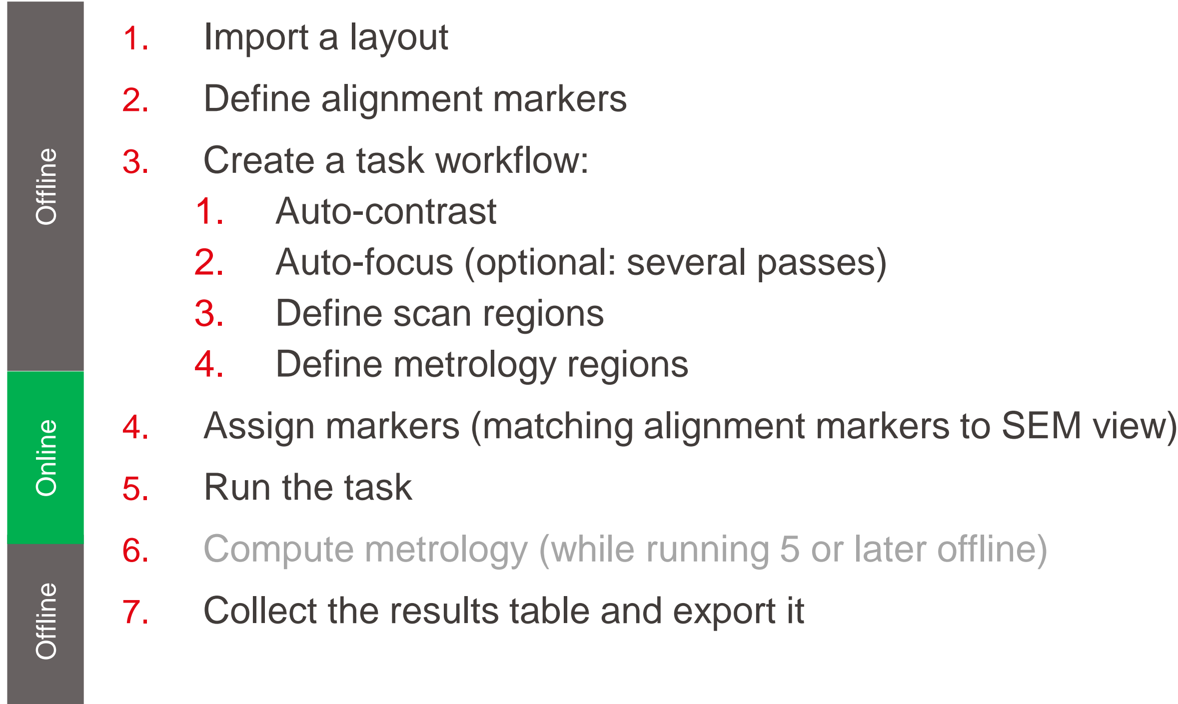
SEM with InSPEC - How does it work?



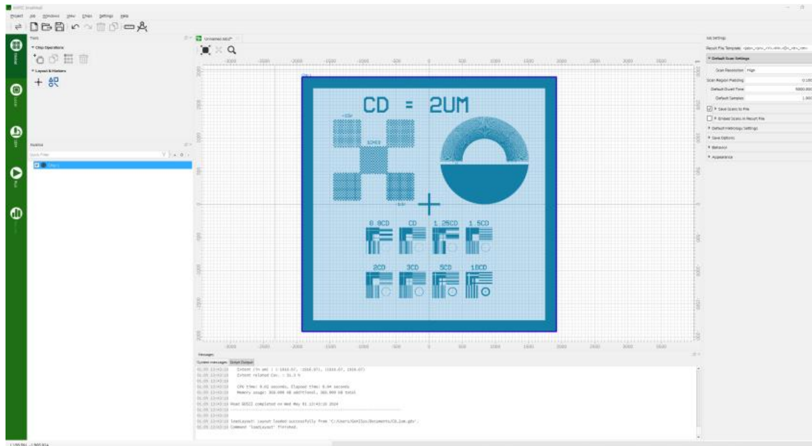
Overview of the Workflow

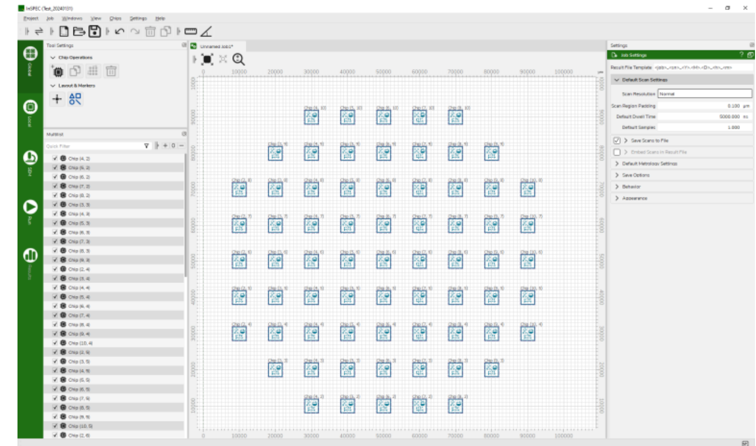


1. Import a layout
2. Define alignment markers
3. Create a task workflow:
    1. Auto-contrast
    2. Auto-focus (optional: several passes)
    3. Define scan regions
    4. Define metrology regions
4. Assign markers (matching alignment markers to SEM view)
5. Run the task
6. Compute metrology (while running 5 or later offline)
7. Collect the results table and export it

1 – Data Preparation - import a layout

- Offline/Online Data preparation
  - Import/create a layout *.gds
  - If desired - replicate with specified pitch (up to wafer scale)





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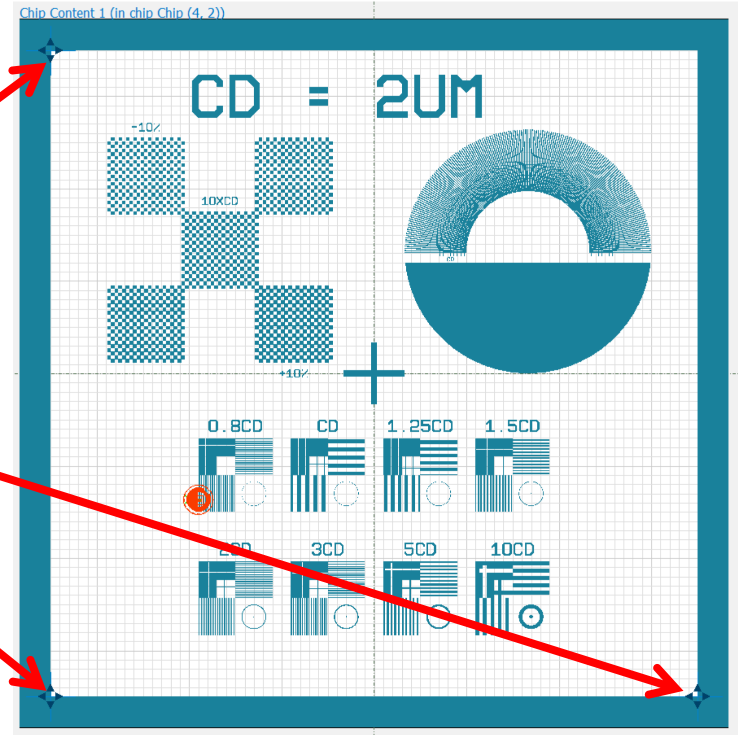
2 – Define alignment markers

3 points on the layout



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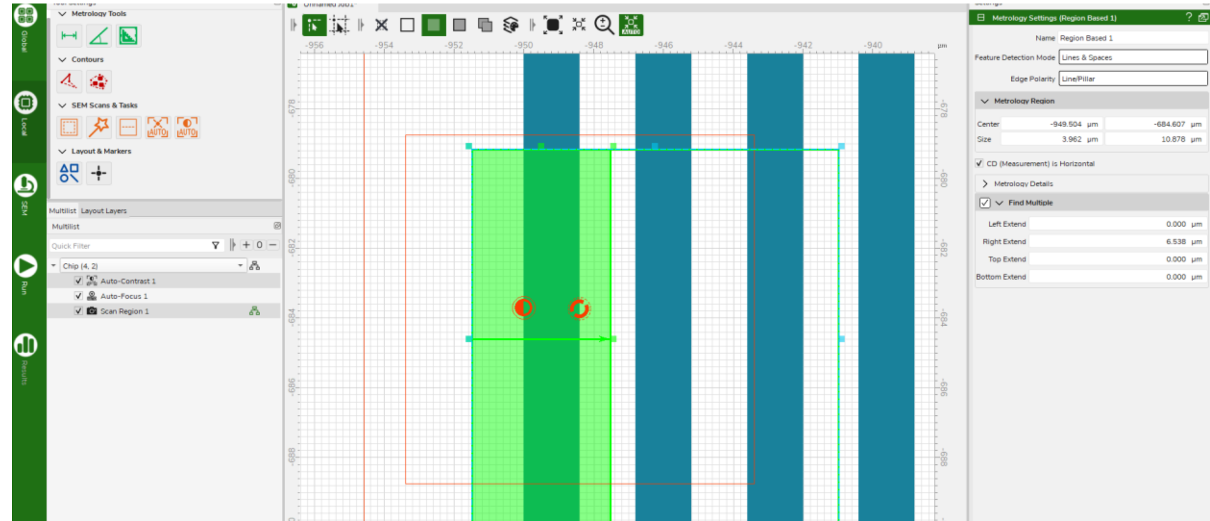
3 – Create a task workflow

1. Auto-Contrast
2. Auto-Focus
3. Create Scans regions
4. Create Metrology Region

5. Define type of shapes
6. Define polarity
7. Options

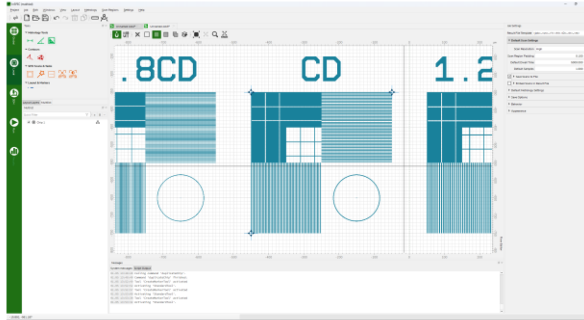
8. Propagate these instruction to all chips (for example)



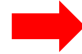
Perform as many **auto-focus** operations as needed during movements
Image registration ensures high precision with the stage

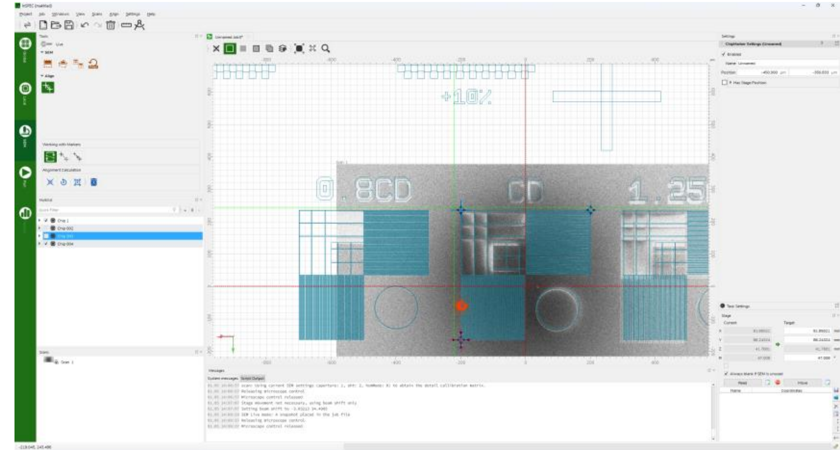
4 – Assign markers

5,6 - Run the task

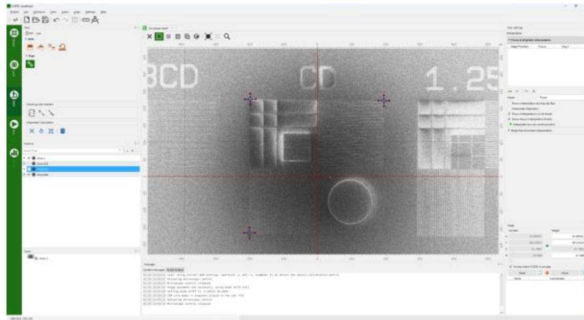


3 points on the layout





Assign markers on SEM view



Scan(s) of these point on SEM view

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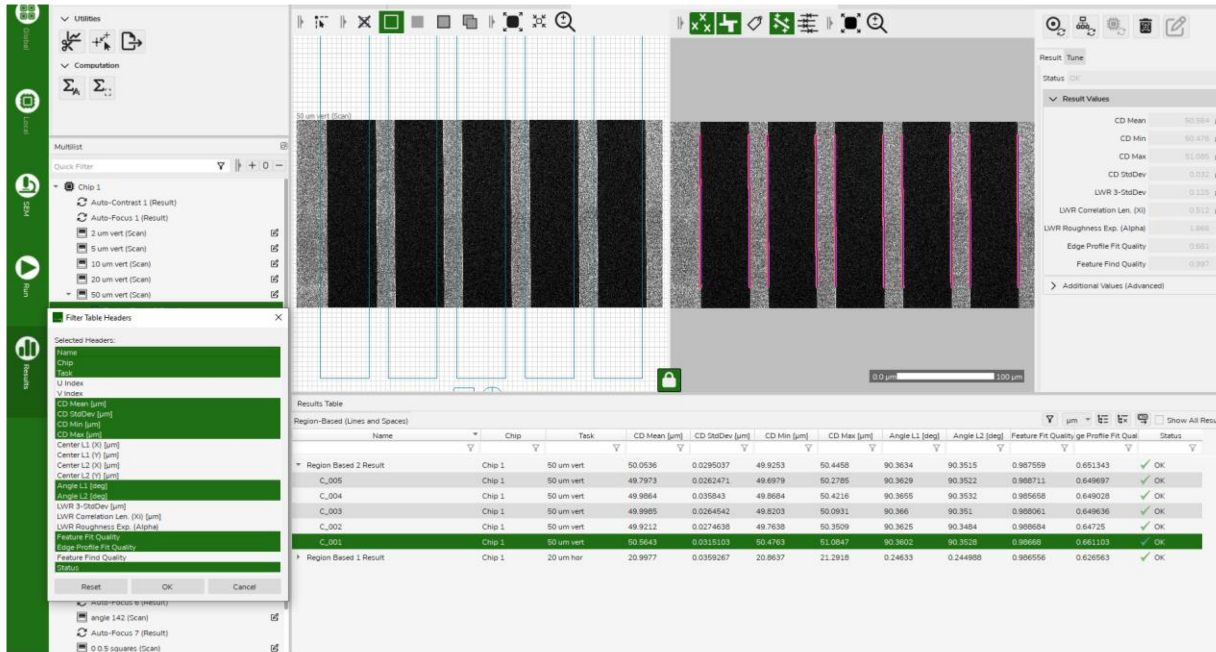
7 – Collect the results



Result table:
CD
CD StdDev
CD min
CD max
Angle L1
Angle L2
Feature fit quality
LWR 3-StdDev
Etc.

Results can be exported as CSV table for post-processing

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Some applications at CMi

Statistical Process Control

DUV Wafer Stepper

Electron Beam Lithography

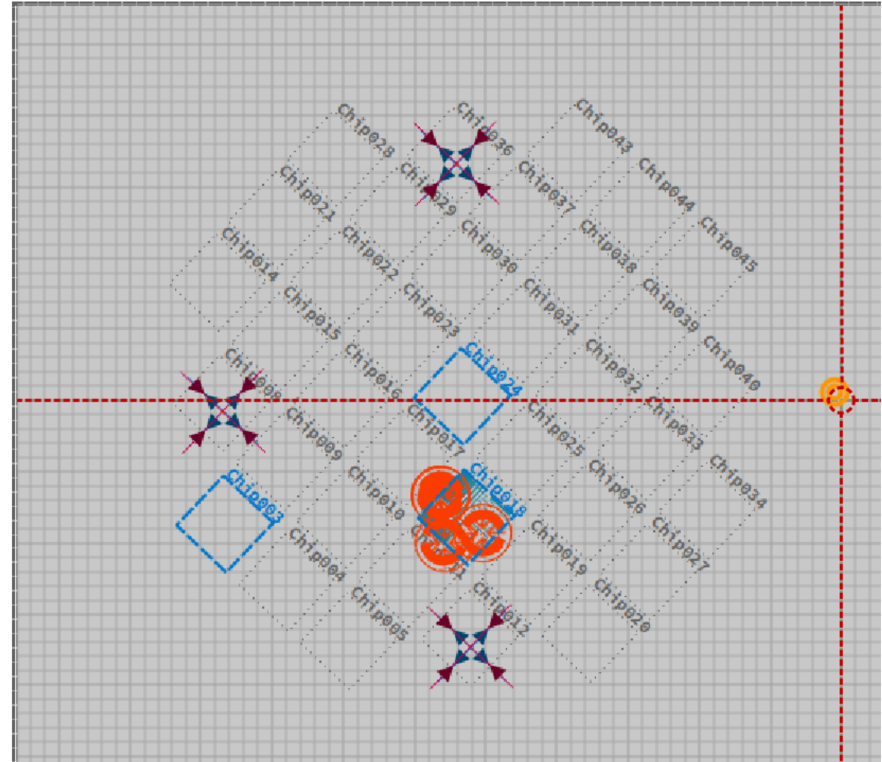
Statistical Process Control

On a weekly basis monitor and control photolitography and etching parameters (etch rates, uniformity)

High volume of measurements on over 20 different tools

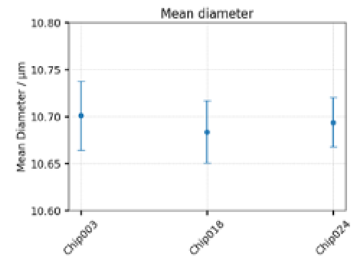
Traditional method:
Manual resist erosion and depth measurements

InSPEC enabled method:
Automated CD SEM metrology

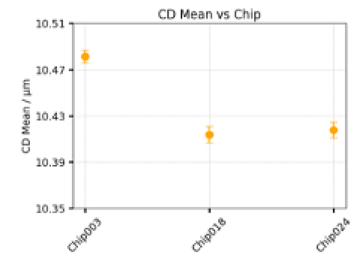


Statistical Process Control

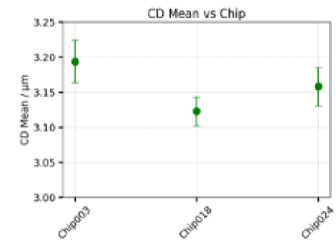
Diameter distribution (plot)



Trench/linespacing variation (plot)

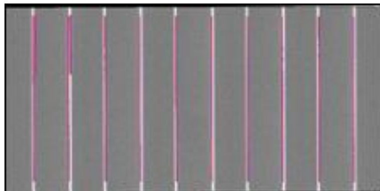


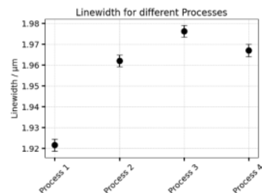
Line width roughness



DUV Wafer Stepper - dose and focus matrix

Trench measurement – line and space



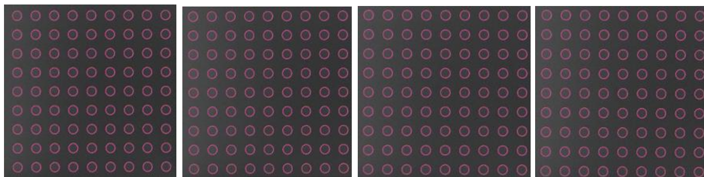


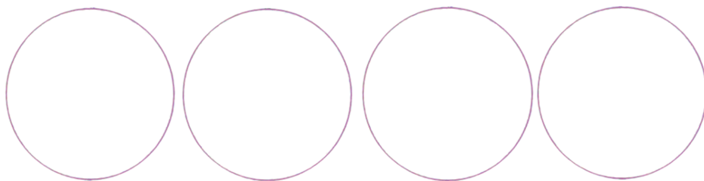
Weekly tool/exposure parameters calibration

Traditional method:
Manual SEM inspection

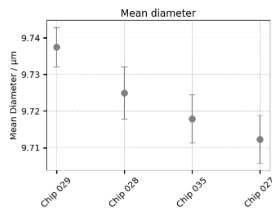
InSPEC enabled method:
Automated CD SEM metrology

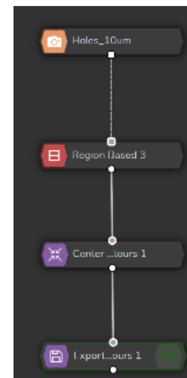
Diameter measurement





overlay of the contours from each image





Example of process flow for trench or diameter metrology

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Electron beam lithography – PEC parameters

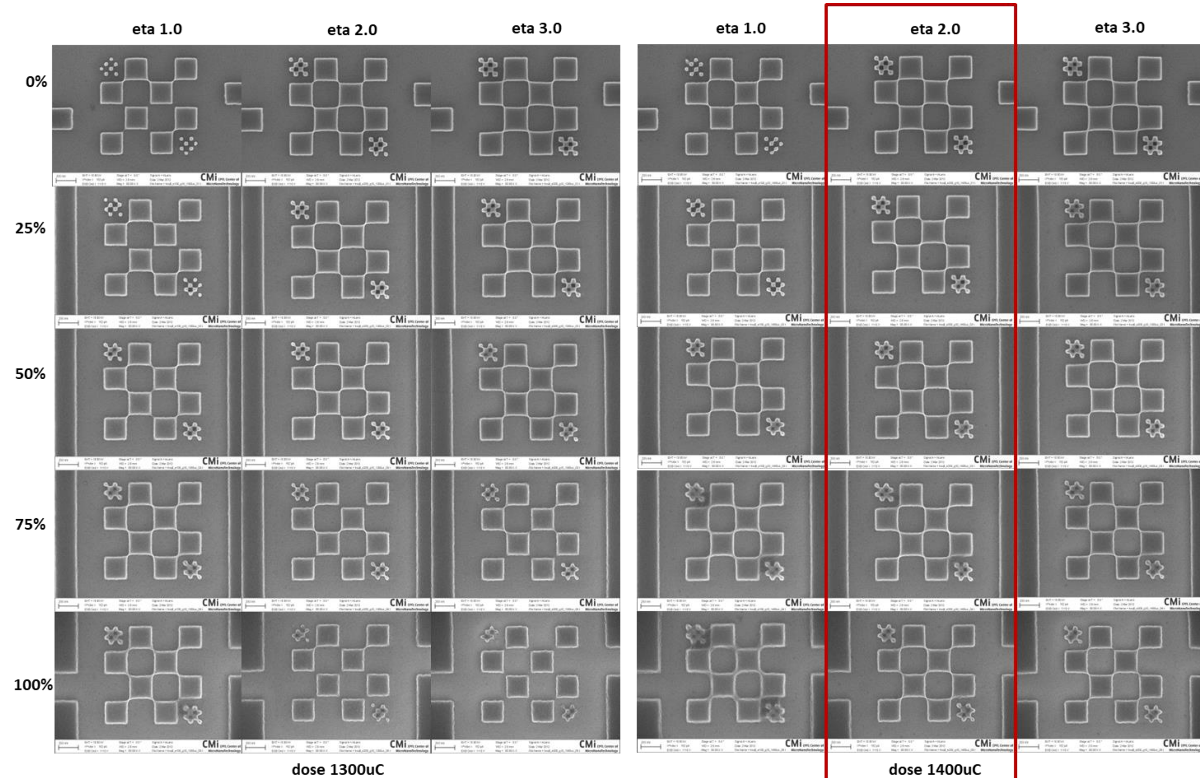
Traditional method

11 doses
3 eta values
5 pattern densities
=
165 images to be taken manually

InSPEC method

Automated image taking

Automated CD measurements



Electron beam lithography – image placement

Stitching error at field boundary analysis

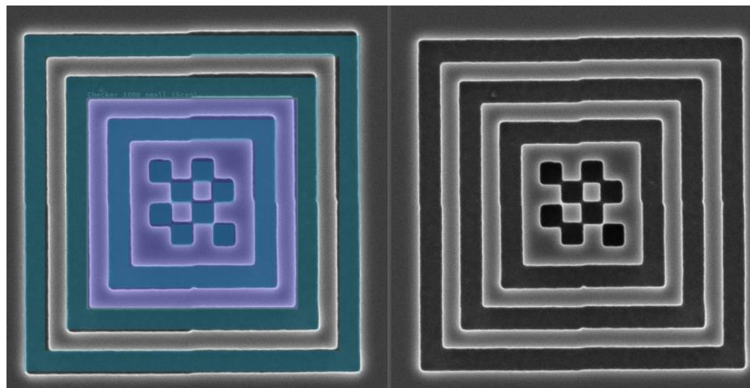
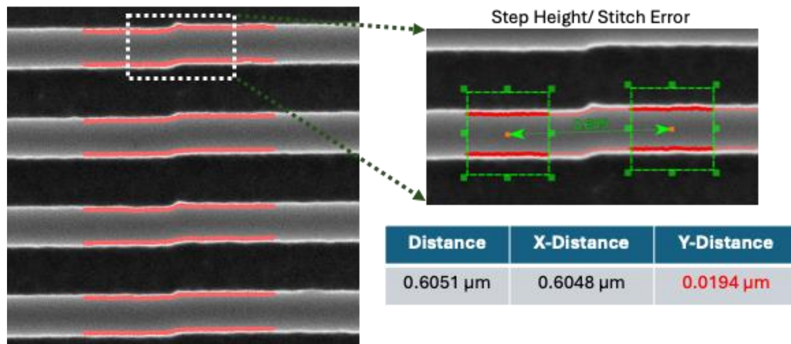


image to layout registration



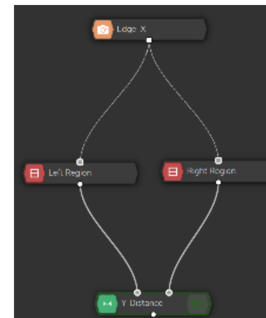
Distance	X-Distance	Y-Distance
0.6051 µm	0.6048 µm	0.0194 µm

Traditional method

Aided by InSPEC

Stitching error measurement by defining metrology regions on either side of the stitch and calculating the distance between their centers.

Process flow customization to build specific characterization



Electron beam lithography – image placement

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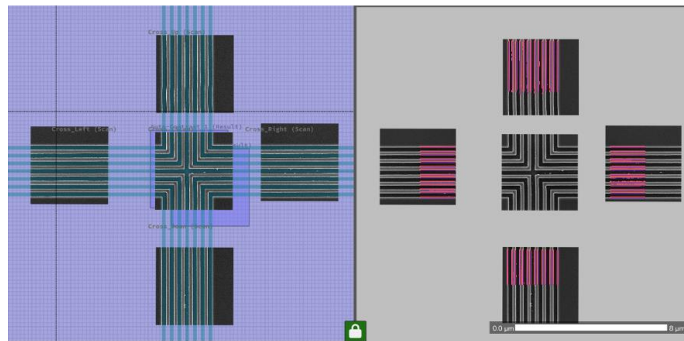
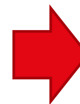
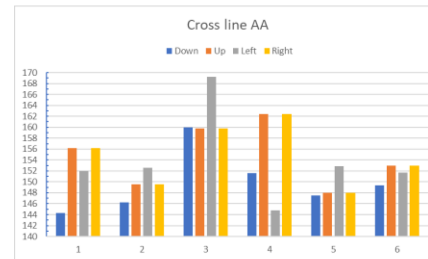
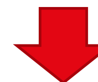
Simple stitching error analysis

Field distortion mapping



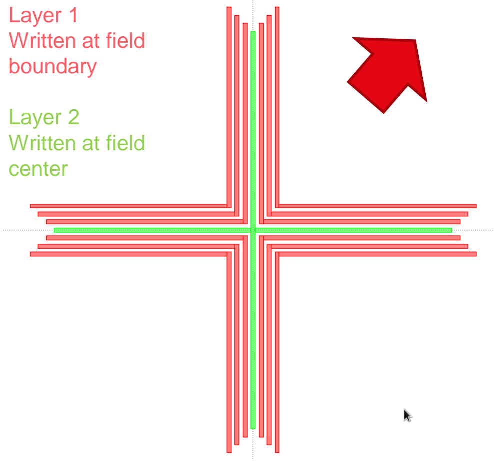


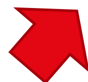




Layer 1
Written at field boundary

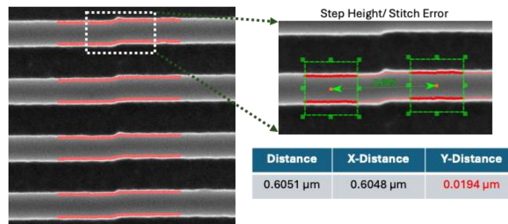
Layer 2
Written at field center





CD metrology based method aided by InSPEC

Traditional method aided by InSPEC



Distance	X-Distance	Y-Distance
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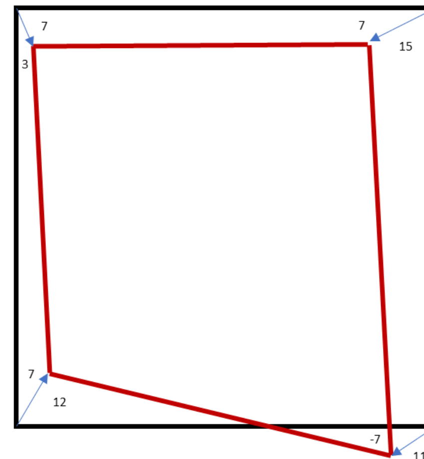

Demands on metrology solution

Flexibility
Small footprint
Accuracy
Repeatability
Self-consistency
Speed
Offline job preparation
Ease of use / fast training
Sufficiency of features
without too much complexity
Supplier support
Reasonable price

Enabling features of InSPEC

Integrated with existing SEM toolset
Offline job preparation
Image to layout registration
Stage movement control
Autocontrast
Autofocus

EPFL
CMi

Thank you

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polytechnique
fédérale
de Lausanne