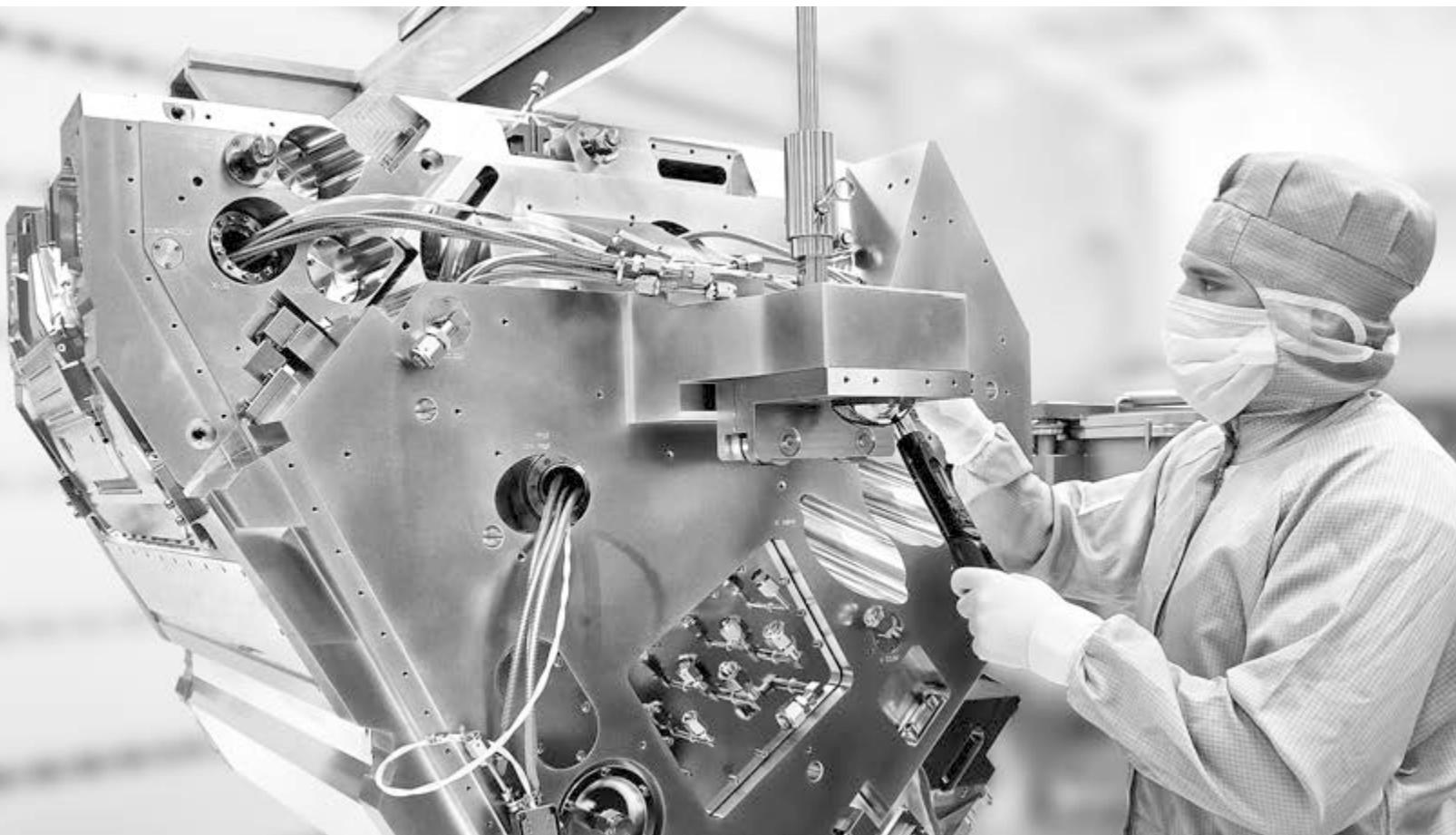


Particular Contamination while EUV-Lithography Optic Assembly



Dr. Rüdiger Düsing

TTC-Conference, CEA Saclay, France, 12th November 2014

Agenda



- 1 Carl Zeiss SMT
- 2 EUV-Projekt
- 3 Cleanrooms
- 4 Measuring Technique
- 5 Process Control
- 6 Simulations
- 7 Qualification

Agenda



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Carl Zeiss SMT

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Sites & Employees



Wetzlar
200 employees



Oberkochen
2,460 employees



Jena
160 employees



Roßdorf
55 employees



2,900 employees

Approx. 1,000 in
Research & Development

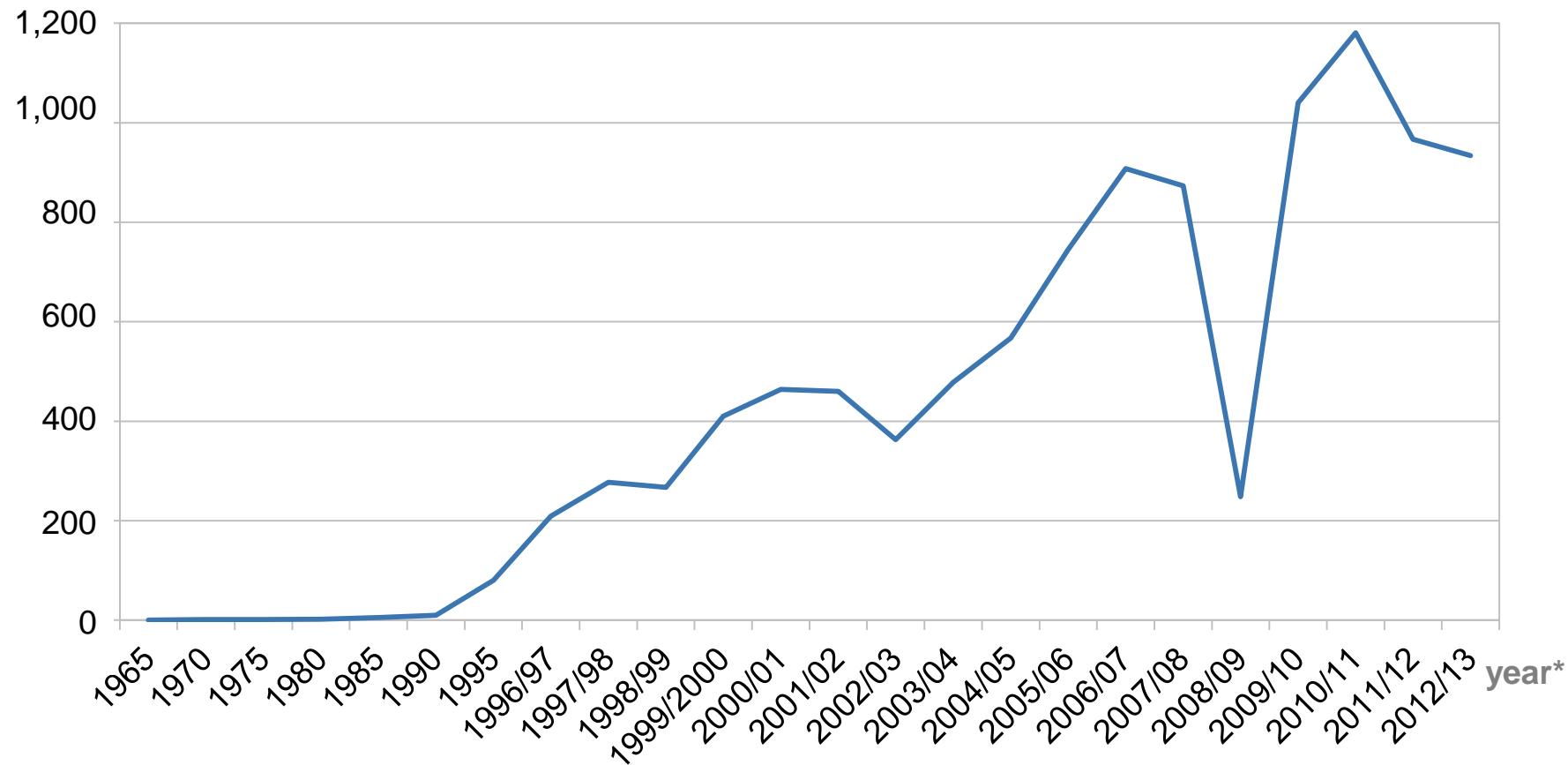
Karmiel, Israel
30 employees



Revenue



in millions of €

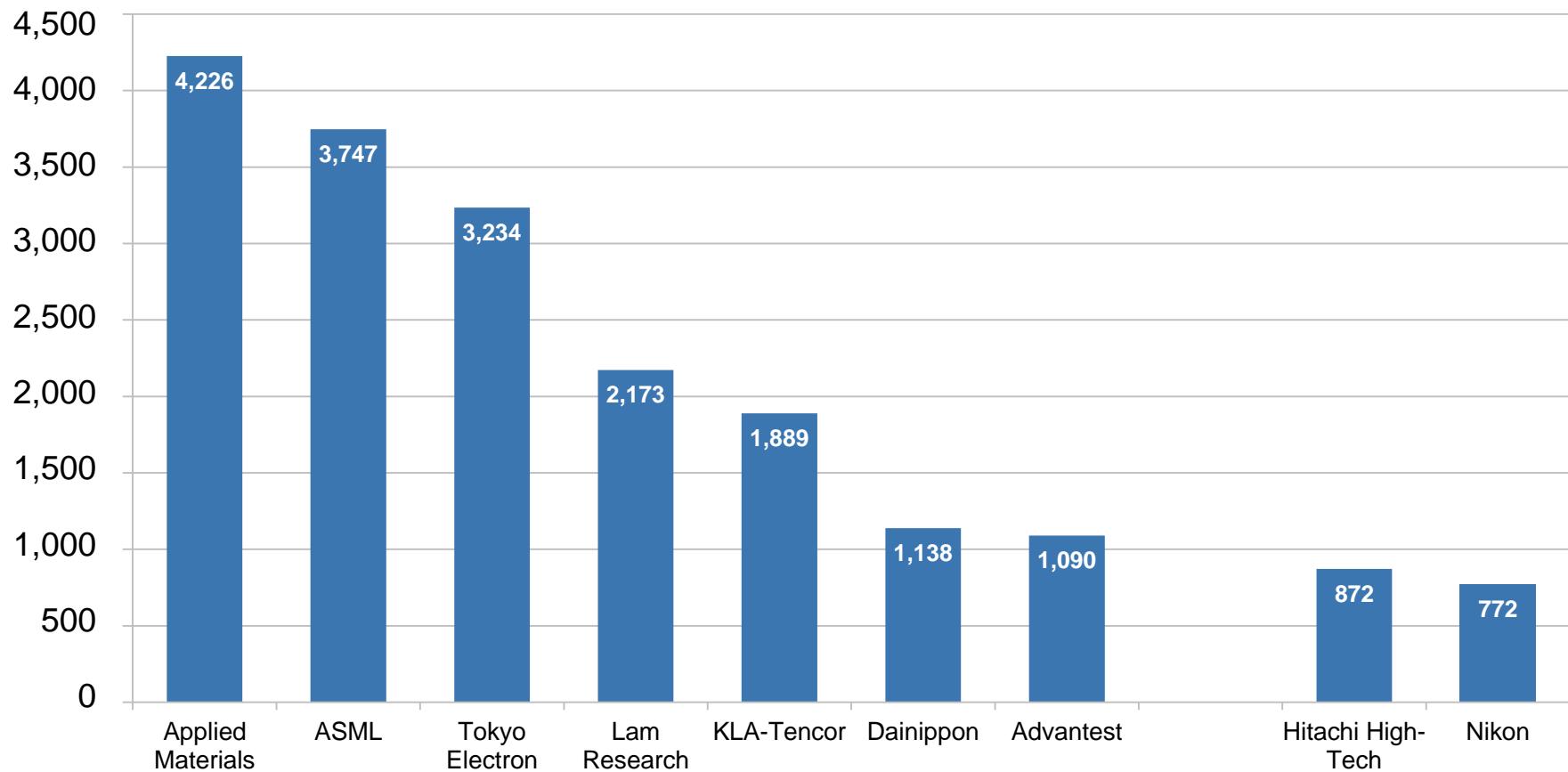


*) Fiscal year start in January until 1995 incl., in October thereafter

Top 10 wafer fab equipment suppliers in 2012



Revenue in millions of €

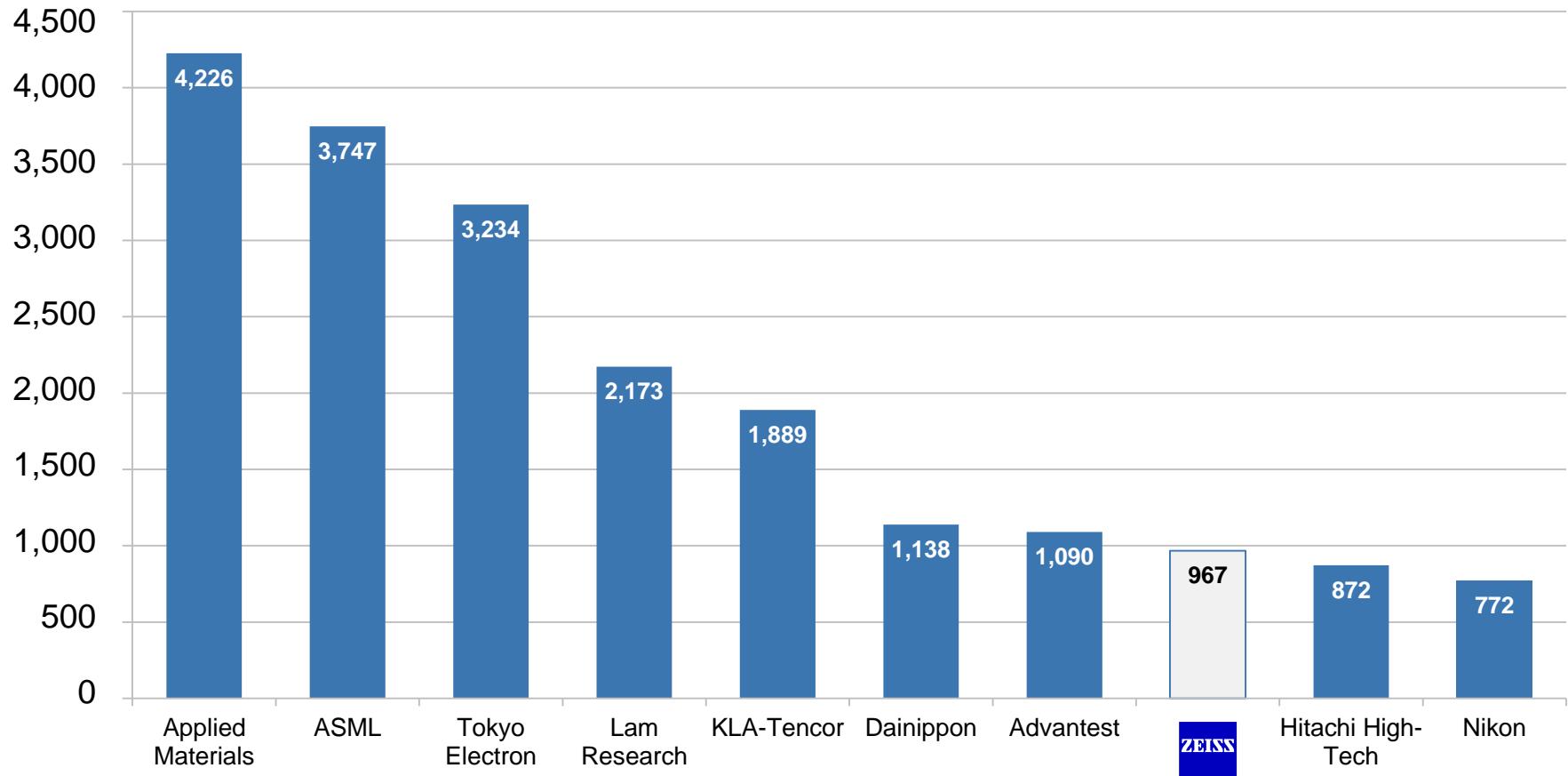


Source: Gartner Dataquest (March 2013)

Top 10 wafer fab equipment suppliers in 2012



Revenue in millions of €



Source: Gartner Dataquest (March 2013)

Agenda



1

2 EUV-Project

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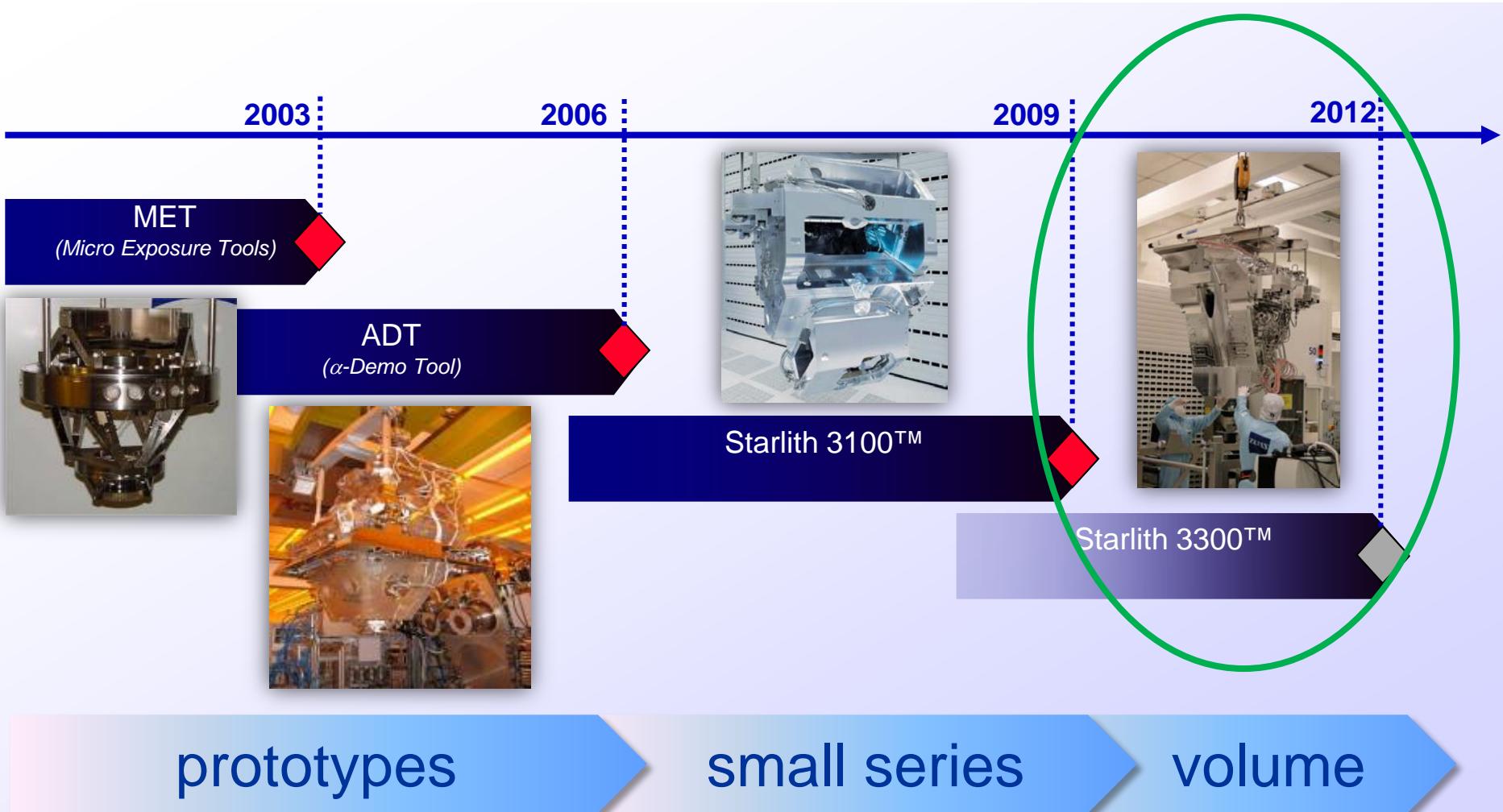
5

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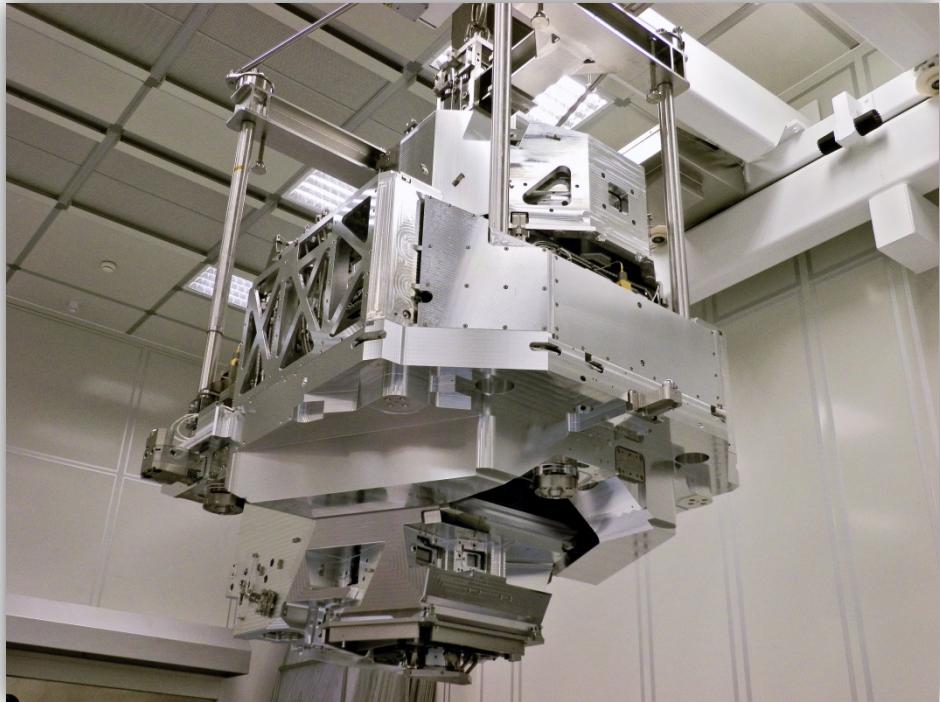
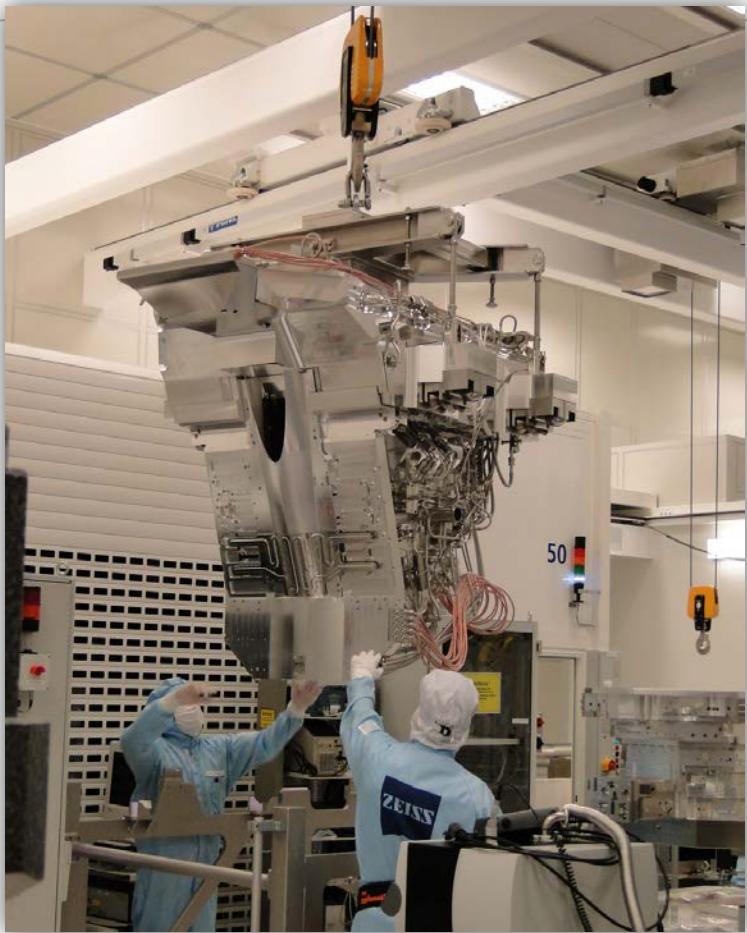
8

EUV program at Carl Zeiss SMT GmbH



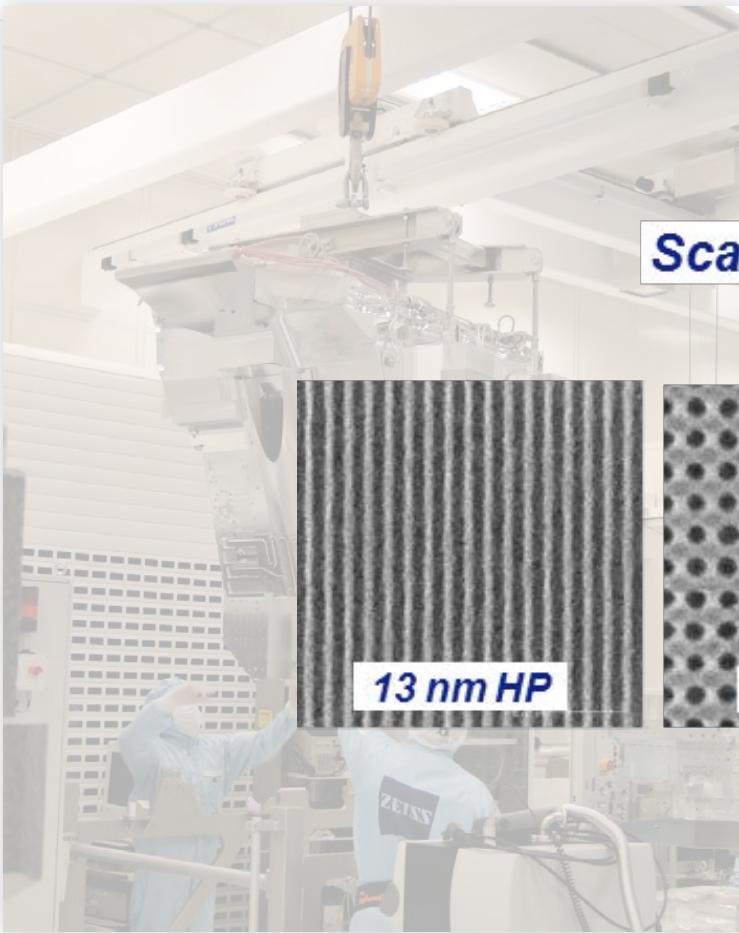
A continuous EUV development program is running for more than 15 years

Starlith™ 3300 optics goes into volume

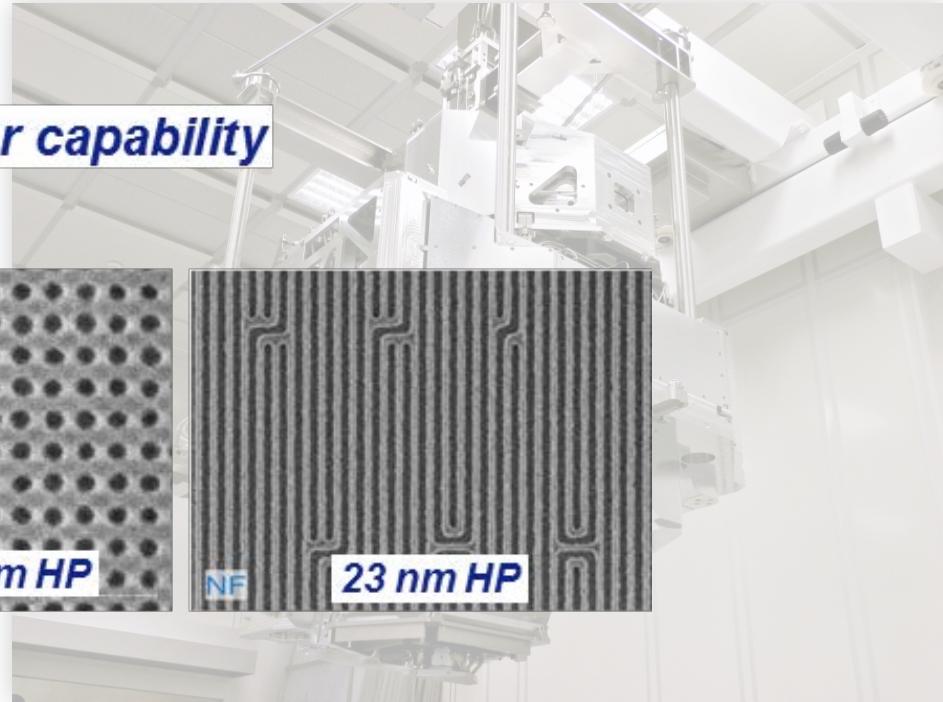
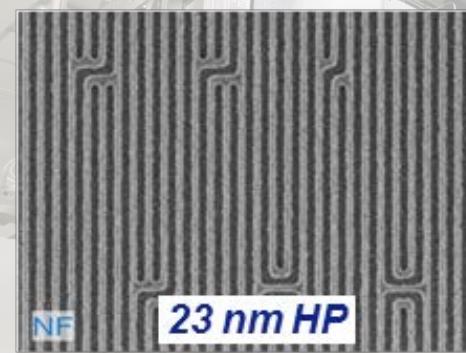
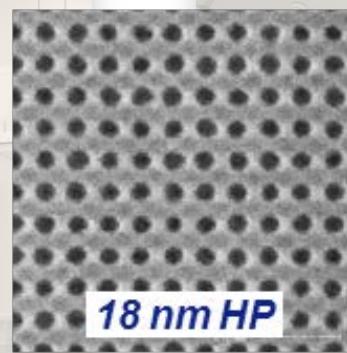
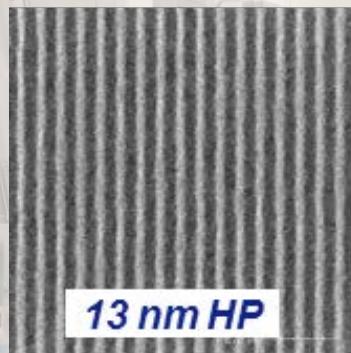


Illuminator
POB
Several customer systems shipped

Starlith™ 3300 optics goes into volume



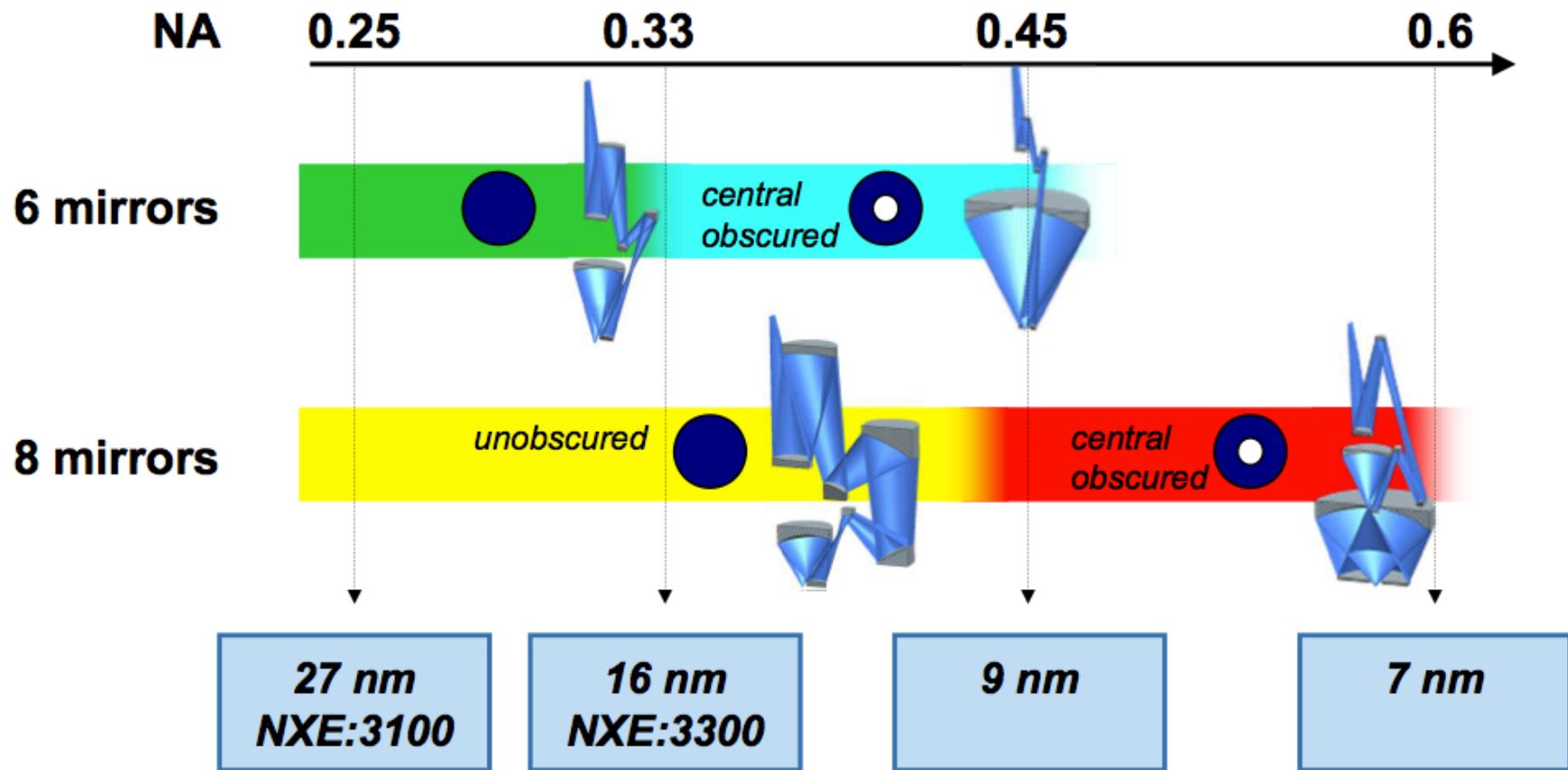
Scanner capability



Illuminator
Several customer systems shipped

POB

We see design solutions for high NA enabling sub-10nm resolution.

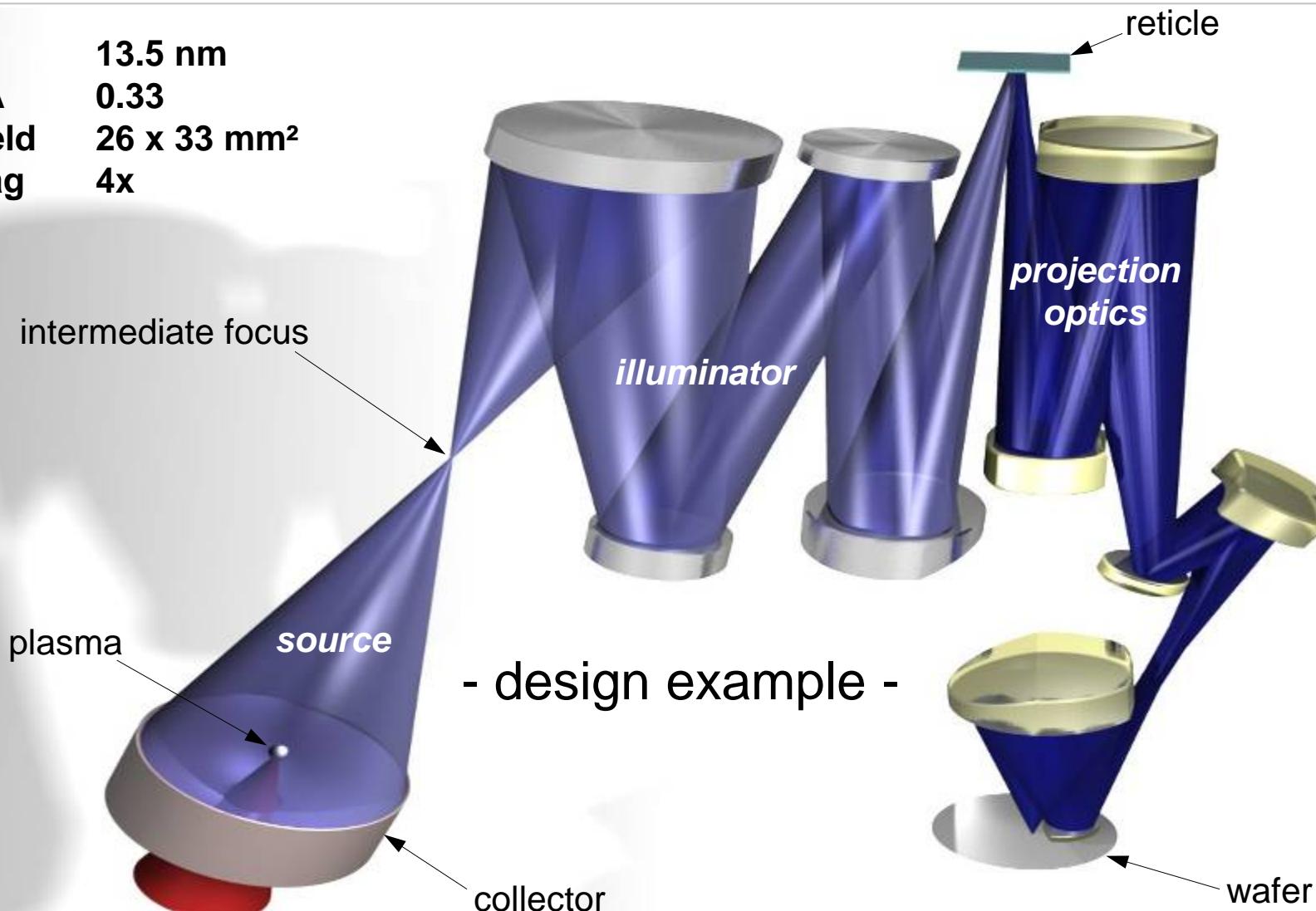


schematic designs – for illustration only.

The optical train – Introduction



λ 13.5 nm
NA 0.33
Field 26 x 33 mm²
Mag 4x



Challenge:

- reach spec for Figure, MSFR and HSFR simultaneously



Computer Controlled
Polishing for
Deterministic Processes



Fast Magneto Rheological Figuring



Ion Beam Figuring:
Atomic Level Figure Control

All processes approved for volume manufacturing

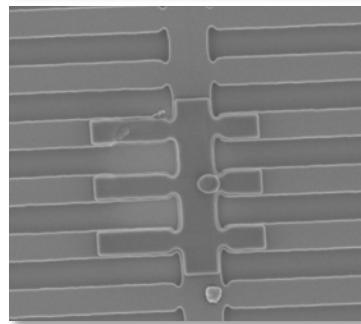
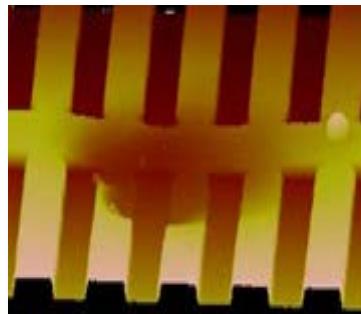
Qualification of Illuminator performance



Mask defects and repairs must be reviewed before printing wafers



AFM image of EUV defect

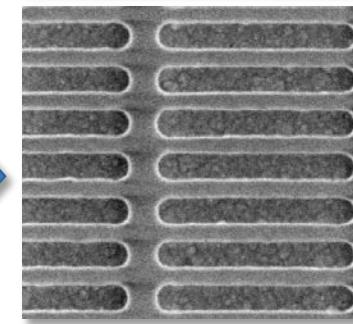
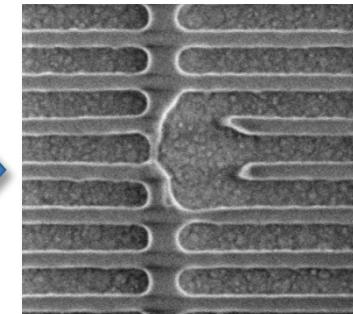


SEM image of EUV repair

Will this
defect
print?

Will this
repair
pass?

SEM image of wafer print



SEM image of wafer print

**AIMS™ provides this information,
BEFORE printing**

AIMS™ EUV without enclosure



Supply compartment

EMC: Inner
(vacuum
handling)

EMC: EUV
Metrology Core

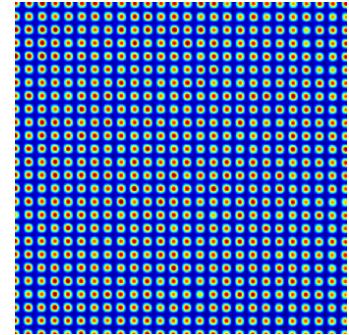
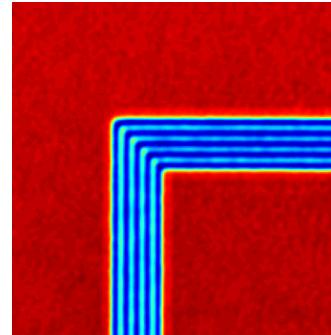
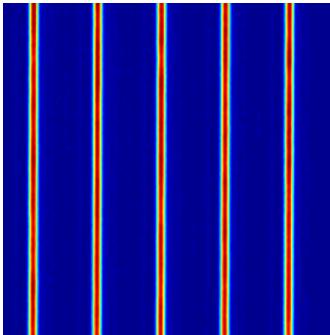
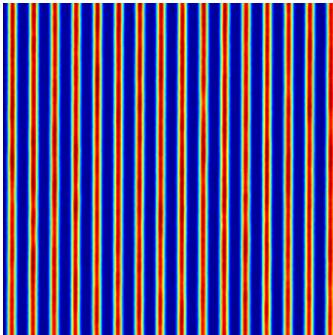
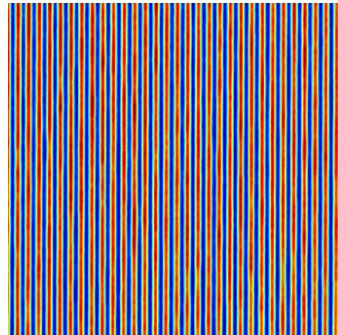
Load port
and outer
handling
unit



AIMS™ EUV Prototype is becoming a reality !
Core system assembled



AIMS™ EUV Prototype Status: First EUV aerial images captured!



CD/Pitch: 64nm / 128nm

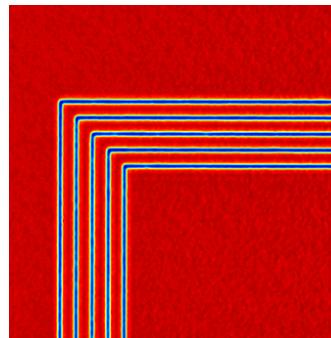
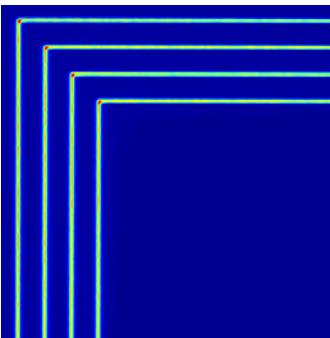
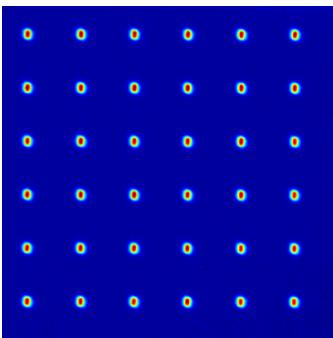
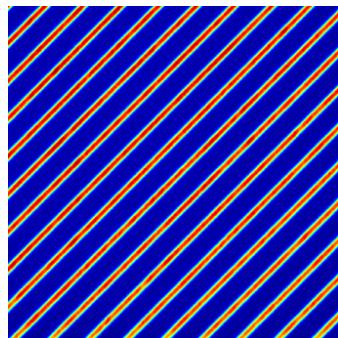
at wafer: 16 nm

64nm / 256nm

64nm / 768nm

64nm / 128nm

80nm / 160nm



CD/Pitch 64nm / 640nm

128nm / 1280nm

64nm / 640nm

64nm / 384nm

6μm x 6μm

- Excellent image quality for First Light images!
- Structure sizes for target application 7nm logic node (64nm at mask) demonstrated

Agenda



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Cleanrooms in Oberkochen



EUV Clothing

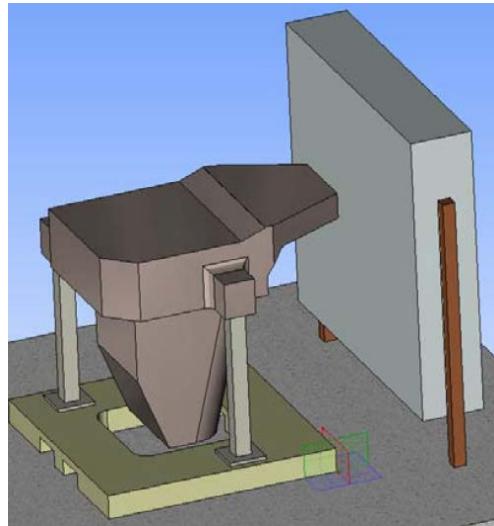
Cleanrooms

| ISO-Class acc. 14644 (US Fed. Std. 209) | none | 7 (10.000) | 6 (1.000) | 5 (100) |
|--|-----------|-------------------------------|------------------------------------|---------------------|
| Cleanroom area [m ²] | 16500 | 3800 | 6700 | at local workplaces |
| Product | Mechanics | i-Line, DUV, VUV, wafer chuck | EUV: Mechanics, Coatings, Assembly | EUV Optic assembly |

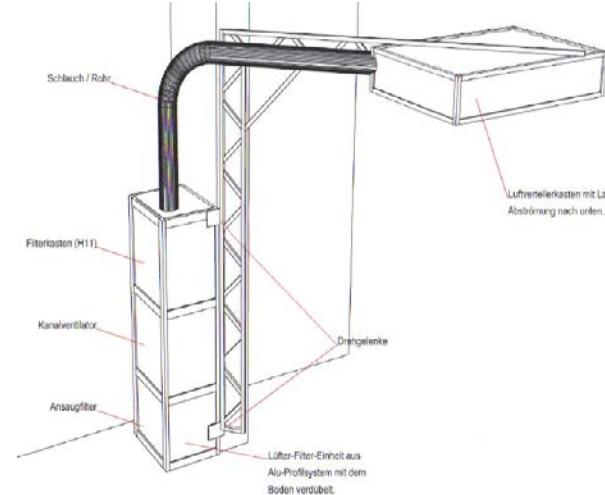
Cleanroom Assembly under Filter Fan Units (FFU)



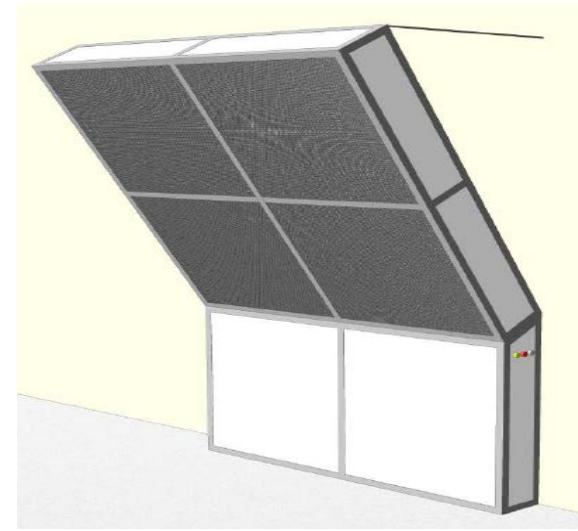
Mobile FFU



Stationary FFU



Rotatable FFU



Stationary FFU

Agenda



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Measuring Technique

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Particle Measurement Techniques at SMT



Direct methods



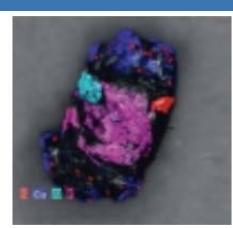
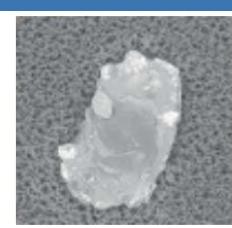
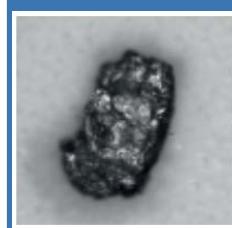
UV / bright light inspection



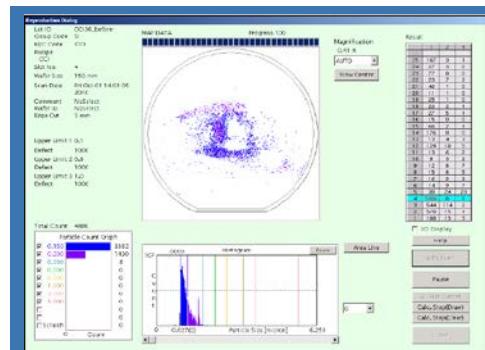
Particle Counter (airborne and from surfaces)



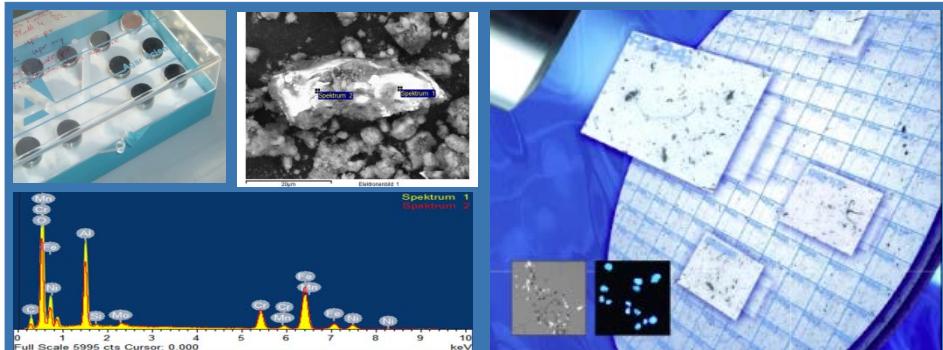
Correlative Microscopy Shuttle & Find



Indirect methods



Particle Detection by Wafer tests



SEM/EDX (C-Tabs, SiO₂ & wafer)

Agenda

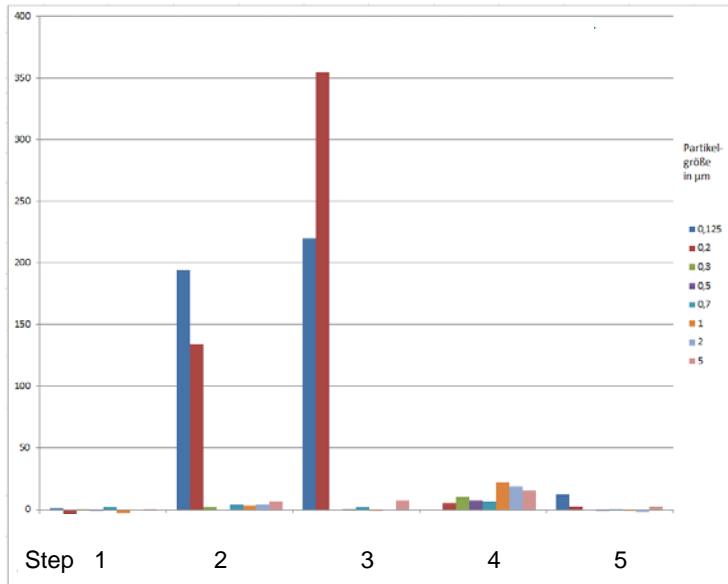
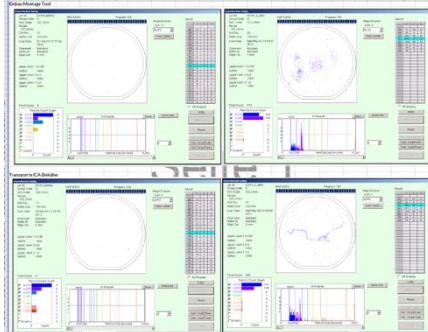
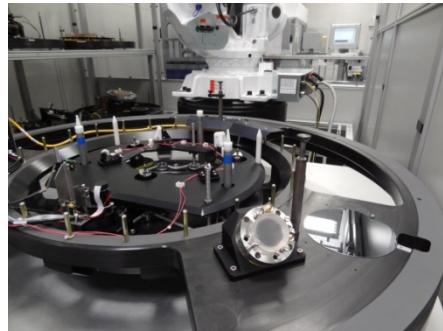


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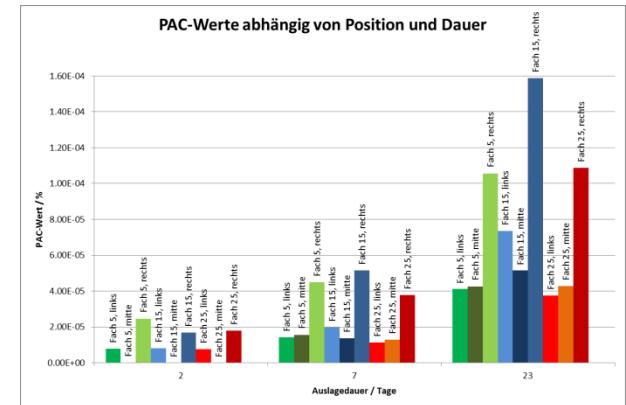
Process Control with Wafers (examples)



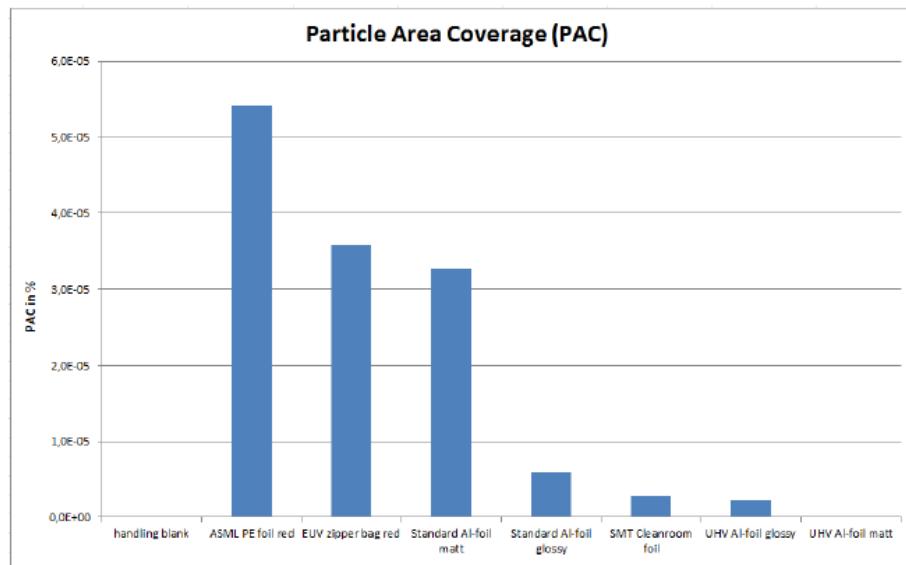
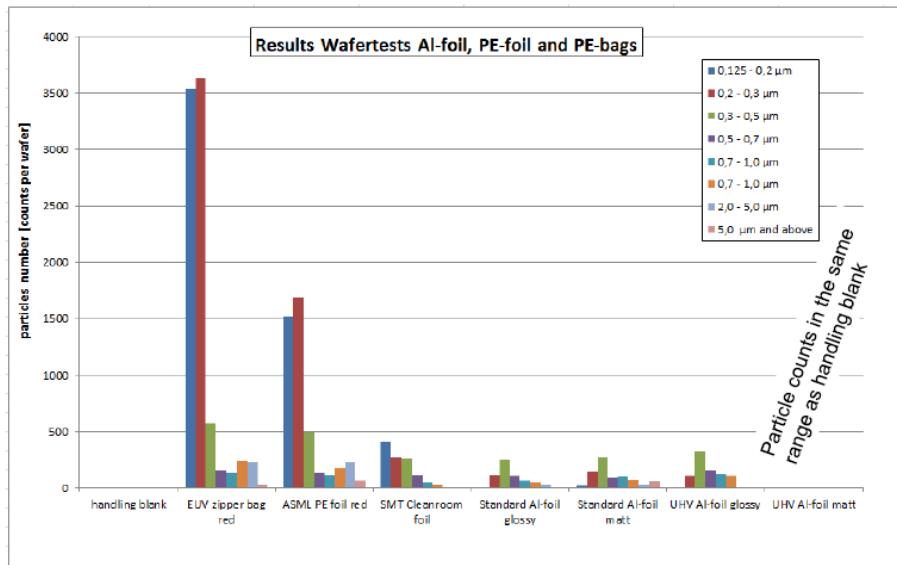
Interferometry



Storage



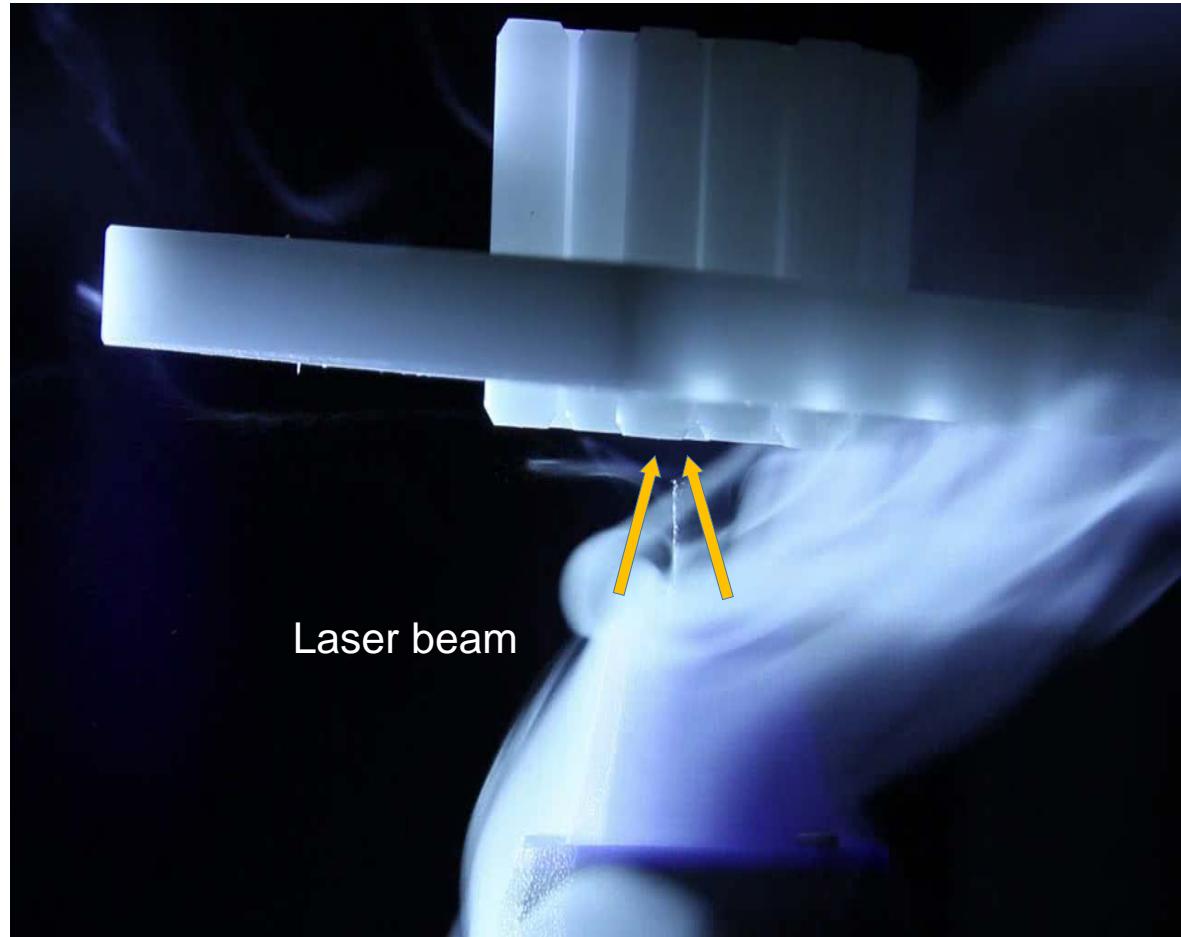
Process Control with Wafers (examples)



Particle Emission Hardware Qualification (examples)



Cable tracking over optic



Laser welding close to optics

Agenda

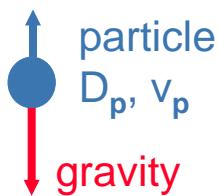
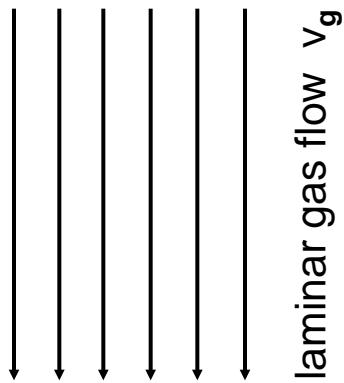


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Particle Transport under EUV Vacuum Conditions



Analytic model

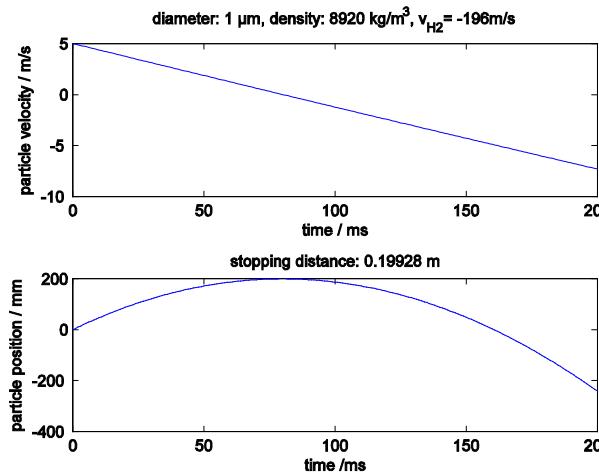


$$m \cdot g \propto \rho \cdot D_p^3 \cdot g$$

Approach

equilibrium of forces of gravity, Stokes friction, Coulomb forces, temperature grad. and inertia

→ as long as gravity and Stokes friction are the only forces there is an analytic solution for $v_p(t)$



Agenda



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- 7 Qualification

Cleanliness Validation



2 Percentage area coverage PAC

The relative area of surface covered by particles is given by the PAC value. Its calculation uses the following assumptions:

- the particles are spherically shaped
- instead of the real size of the particle the size class of the detector is used as particle diameter D_p

The N_{tot} particles are approximated by a sphere with diameters D_i and the area covered by the particles A_p then reads:

$$A_p = \sum_{i=1}^{N_{tot}} \frac{1}{4} \pi D_i^2, \text{ where } N_{tot} = N(0.3) + N(0.5) + \dots + N(10) + N(25)$$

Finally, the fraction of the surface covered by the particles is given by

$$PAC = \frac{A_p}{A_{tot}} \cdot 100\%$$

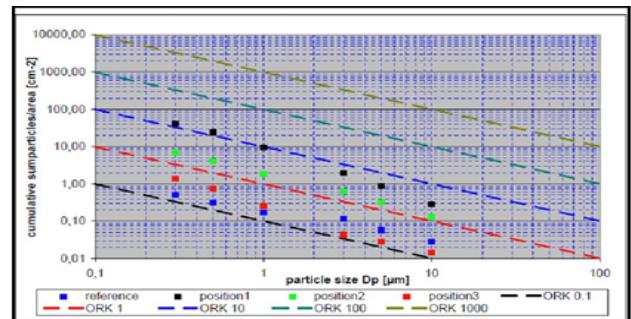
where A_{tot} is the total area considered, e.g. of a mirror.

When measuring the cleanliness, A_{tot} is the surface area that is probed with a certain particle detector.

Example: Using the differential data of the example in Chap. 1 and the scanning area of $A = 69.64 \text{ cm}^2$ yields

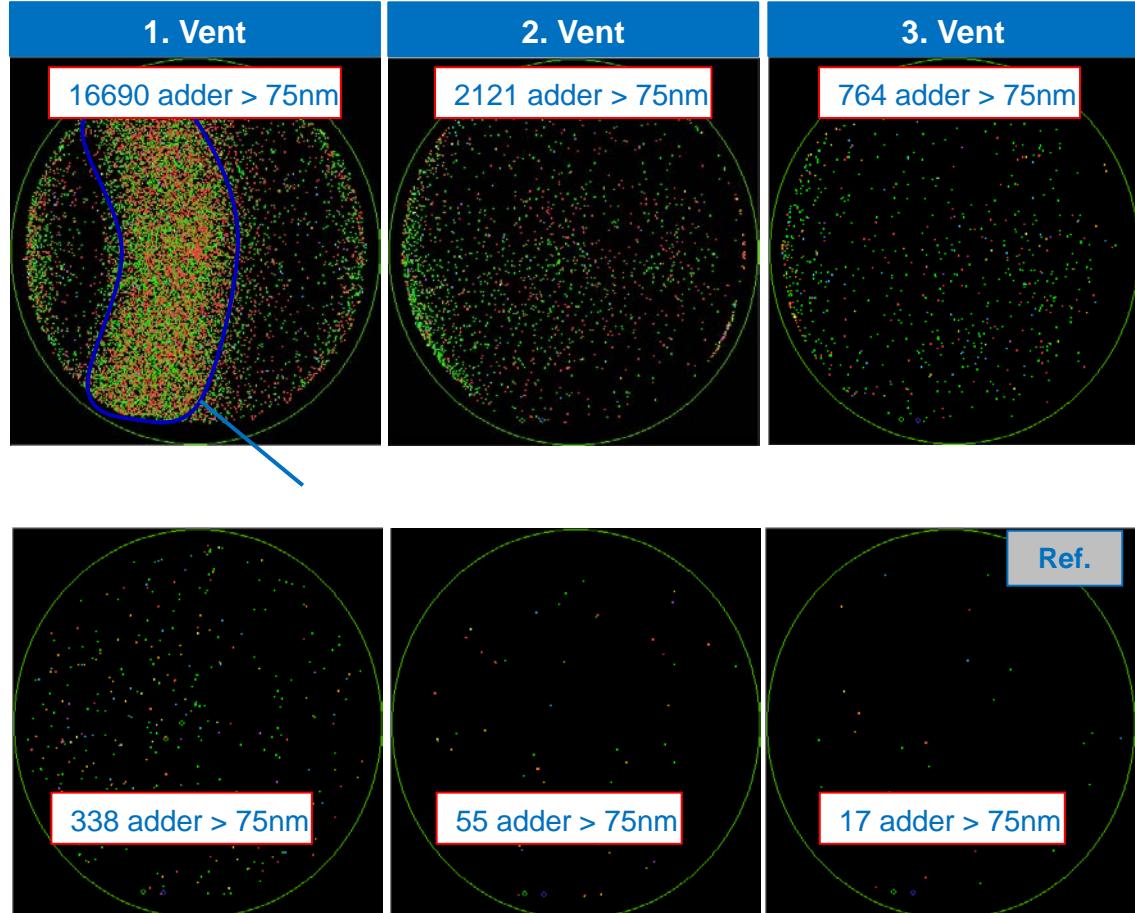
| | | |
|-------------|---------|------------------------------|
| reference: | ORK 1 | PAC = $2.5 \cdot 10^{-6} \%$ |
| position 1: | ORK 100 | PAC = $3.9 \cdot 10^{-5} \%$ |
| position 2: | ORK 10 | PAC = $1.3 \cdot 10^{-5} \%$ |
| position 3: | ORK 1 | PAC = $1.4 \cdot 10^{-6} \%$ |

Example



| particle size / µm | ORK 0.1 | ORK 1 | ORK 10 | ORK 100 |
|--------------------|-------------------------|-------------------------|-------------------------|-------------------------|
| 0.3 | 0.13 | 1.3 | 13 | 130 |
| 0.5 | 0.1 | 1 | 10 | 100 |
| 1.0 | 0.07 | 0.7 | 7 | 70 |
| 3.0 | 0.013 | 0.13 | 1.3 | 13 |
| 5.0 | 0.01 | 0.1 | 1 | 10 |
| 10 | 0.01 | 0.1 | 1 | 10 |
| PAC | $1.16 \cdot 10^{-6} \%$ | $1.16 \cdot 10^{-5} \%$ | $1.16 \cdot 10^{-4} \%$ | $1.16 \cdot 10^{-3} \%$ |

Qualification



Venting through the system with catching particles on wafer



We make it visible.