Bruker ASC

EUVL-2012 P-MA-27

R&D Actinic Blank Inspection Microscope

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Introduction

Actinic blank inspection (ABIT) is still an open keystone of EUVL infrastructure. As discussed e.g. within the community such tools are required with high throughput at least at all mask suppliers.

As reported earlier, we have intensively studied this task in the past. The three top-level expectations for the production ABIT are:

- sensitivity to buried defects of less than 30 nm in width and 1 nm in surface height,
- referencing positions to better than 10 nm and
- accomplishing the task of finding all defects on a mask blank within 45 minutes per blank.

Solving all tasks simultaneously is pushing the demands on the critical components - EUV source, detection system and stages - to their limits, which is significantly driving the development effort and the tool price. We found that the key parameter for tool layout is the blank's roughness and the resulting EUV flare, which strongly limits usable parameter space, denying utilization of most efficient defect detection solutions.

Relaxing throughput requirements as a driving parameter allows solving the task much more efficiently and / or allows targeting for higher performance with respect to sensitivity.

Based on our studies for a production ABIT, we decided to concentrate our research resources on realizing a demonstrator for an R&D ABIT, which is focused on the core task of finding and analyzing actinic defects in research laboratories, without prioritizing throughput, automation and position referencing in a first step. This allows for significant tool cost reduction, and, consequently, for faster dissemination of the technology, which will be beneficial not only for the EUV defect inspection community but can also speed up the process of implementation of EUV lithography in HVM.

We present the concept and the implementation status of the stand-alone R&D ABIT demonstrator. Access models will be discussed.

Funding by the German minster for Science and Education (BMBF) within the project " 13 N10572: "EUV mask" in the consortium "EUV Lithographie für den 22nm Knoten" is appreciated.

Results with the PoP setup

Experimental results were obtained with the Proof of Principle (PoP) actinic Schwarzschild objective based microscope operating in dark field mode with an EUV-LAMP discharge source from BASC.

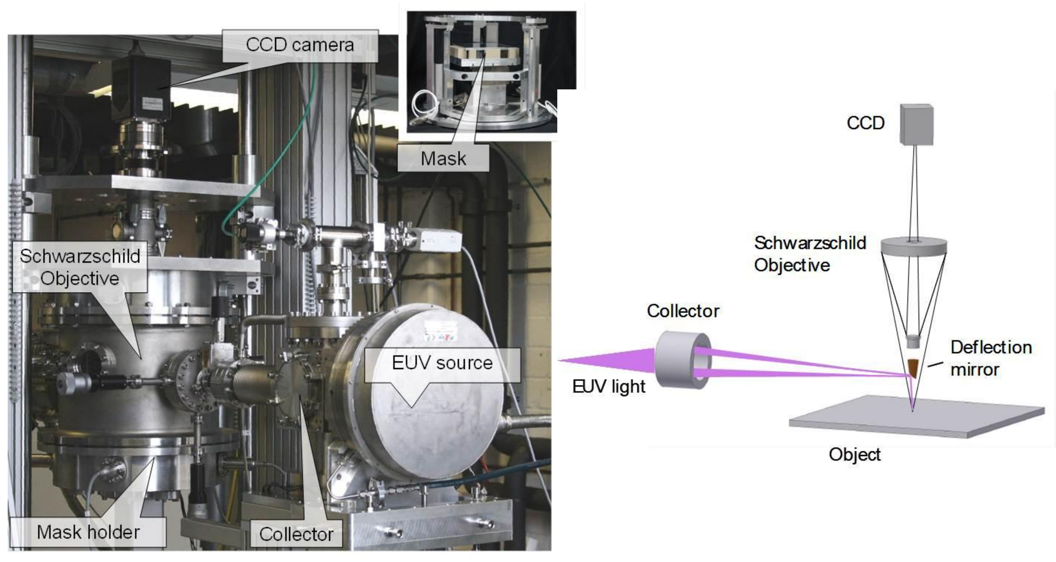


Fig. 1 Photo of the PoP EUV dark-field microscope and of mask holder with 5-axis nanometer precision positioner (inset) (left) and scheme of the setup (right)

Programmed structures (bumps and pits) and natural defects both on multilayer mirrors have been investigated and characterized by AFM, the smallest defect is shown:

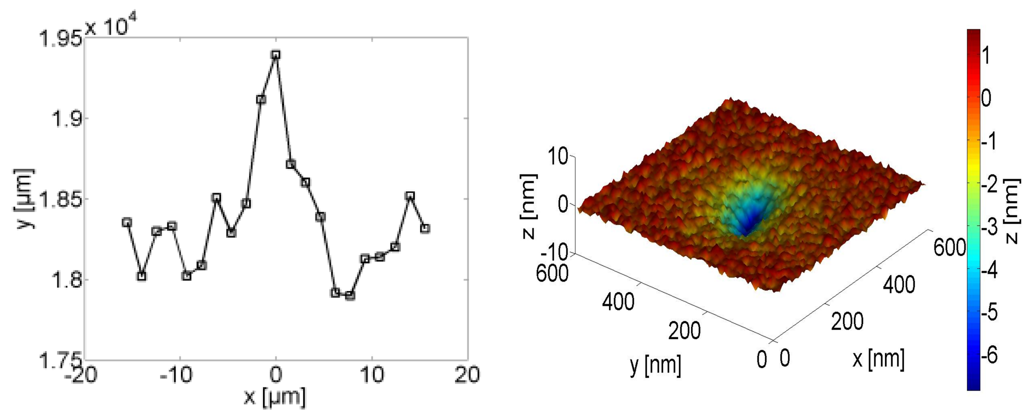


Fig. 2 : Profile of a dark field EUV image of ML mirror sample (left) and the corresponding AFM scan (right). The equivalent sphere diameter is 45 nm, the height is 7 nm.

R&D ABIT

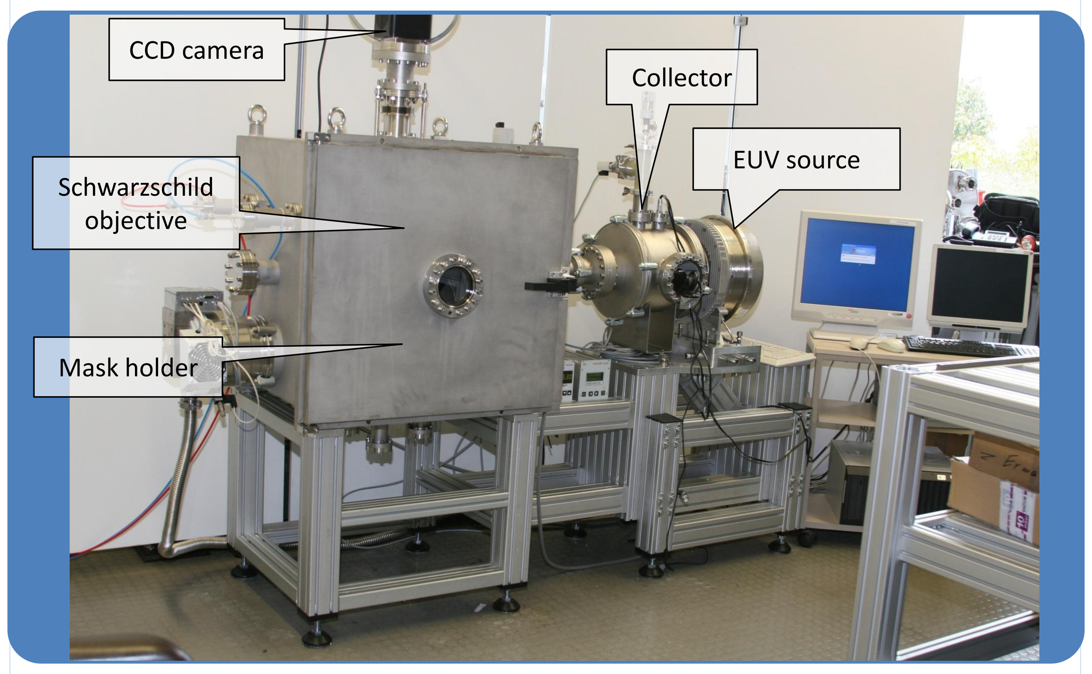
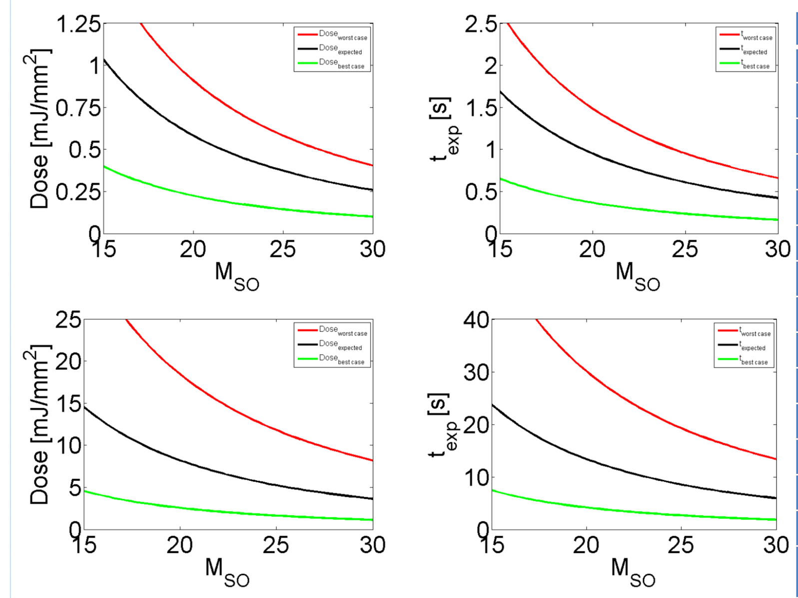


Fig. 3 Photo of the R&D ABIT

Defect sensitivity

Limitations caused by detector, optics, sample movement and source performance. Goal is to have SNR = 6 and detect 30 nm defects, for extendibility also 20 nm sensitivity is shown:

$$SNR = \frac{S_{defect}}{\sqrt{S_{roughness}}} \qquad Dose \sim \frac{1}{A_{defect}{}^2 \eta_{CE}{}^2} \qquad t_{exp} \sim \frac{Dose}{P_{source} \cdot A_{source}}$$



Parameter	Worst case	Expected case	Best case
QE_{CCD}	0.40	0.40	0.60
$\eta_{scatt\text{-}flare}$	0.02	0.015	0.01
$\eta_{scatt\text{-}defect}$	0.40	0.40	0.40
$\eta_{collect\text{-}flare}$	0.15	0.20	0.25
$\eta_{collect\text{-}defect}$	0.20	0.25	0.30
R_{SO}	0.36	0.36	0.36
d_{pixel} [µm]	13	13	13
$R_{deflection}$	0.45	0.45	0.45
T_{filter}	0.30	0.30	0.30
T_{gas}	0.70	0.70	0.70
$R_{collector}$	0.45	0.45	0.45
$\varphi_{obj\text{-}coll}$ [°]	5	5	5
M_{coll}	6	6	6
d_{source} [µm]	400	400	400
P_{source} [W/2π/2% b.w.]	1	1	1

Fig. 4 Required dose in the object plane to achieve SNR = 6 for 30 nm defects (1st row, left), corresponding exposure time (1st row, right); Required dose and corresponding exposure time for 20 nm defects and the same SNR (2nd row) and table of used parameter.

Simulation model based on diffraction distribution of a pinhole has been developed to calculate the amount of detectable photons as a function of defect diameter. The model has been cross checked by the experimental results from natural defect inspection:

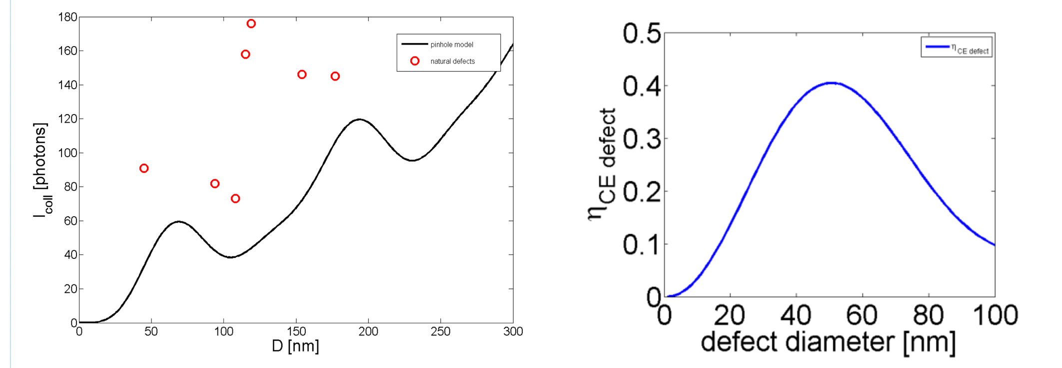


Fig. 5 Number of photons collected by CCD from a single defect - simulated by pinhole model for irradiation dose of 1.6 mJ/cm² (all losses in the system are considered) in comparison with investigated natural defects (left), collection efficiency of scattered light from a defect as a function of its size (right).

For observations of the dose in the object plane an in-vacuum CCD can be inserted and the EUV spot monitored.

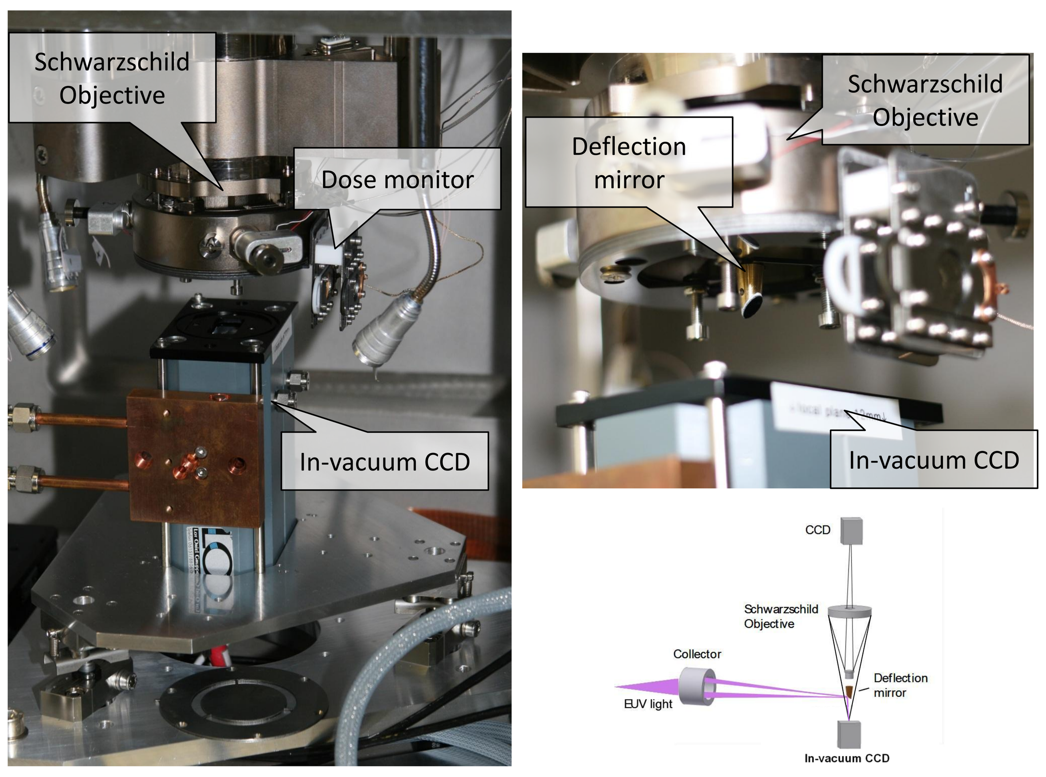


Fig. 6 In-vacuum CCD with water cooling down to -60°C for monitoring of the EUV focal spot in the object plane (left and top, right) and corresponding scheme of the setup (bottom, right).

Results

The EUV spot size in the object plane has been simulated in ZEMAX and measured with an in-vacuum CCD camera. The spot size of the simulation as well as the spot size of the experiment shows a FWHM of 4mm:

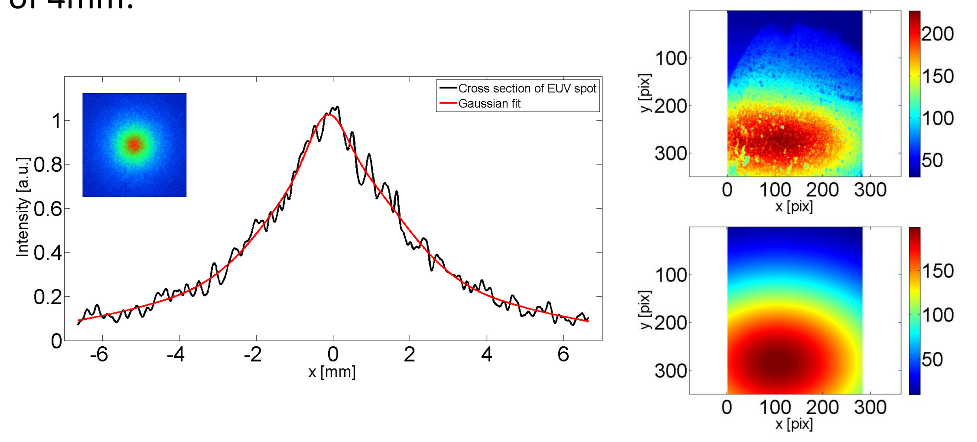


Fig. 7 Cross section of the simulated collector focal spot (left, inset), pinch size: 0.25x3.8mm (left), measured focal spot (top, right) and 2D-gaussian fit (bottom, right), pixel size of 13µm.

The EUV light flux can be monitored during exposure without additional light losses, using a dose monitor:

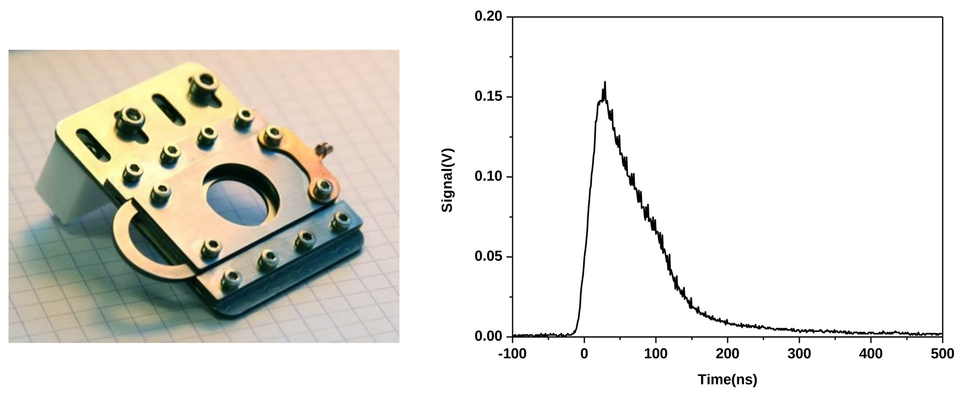


Fig. 8 Dose monitor (left) and experimental result of light flux signal during EUV exposure (right)

Modular concept

System has a modular design to add further components such as bright field resolving observation or reflectivity monitoring.

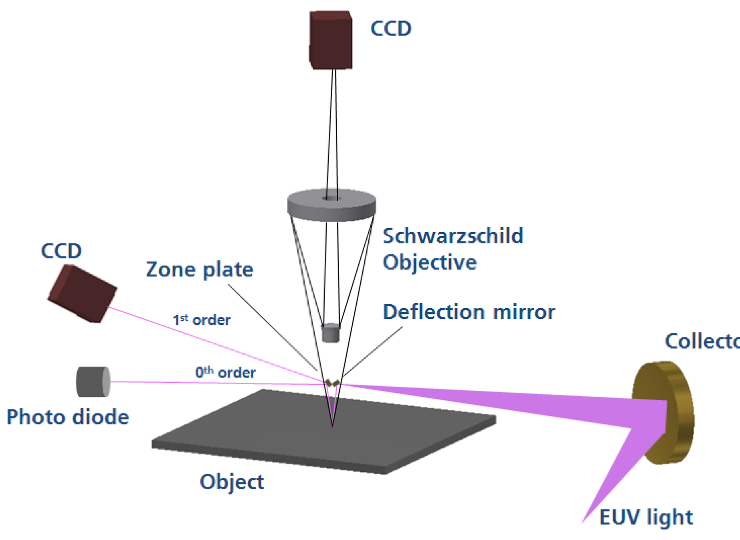


Fig. 9 Scheme of the R&D ABIT microscope with the expansion of full collector, bright field beam path and reflectivity monitoring

Specifications and upgrade possibilities of the R&D ABIT:

Component	PoC	Upgrade
Source [W/2π/2%b.w]	1	30
Collector efficiency	0.4%	45%
Scan range x-y	±25mm	> ±75mm
Camera speed	4.4fps	9.8fps
Defect localization accuracy	650µm	10nm
Zone plate based bright field operation	-	1000x
Reflectivity monitoring	-	✓
Loadlock	-	✓
Clean room environment	-	✓
Vibration damping	-	✓

Conclusions

- Proof of principle operation has been shown with the PoP-setup
- Limitations have been analyzed – M_{SO} = 21 is suitable
- Monitoring of the incident light flux during EUV exposure is implemented without additional light losses
- In-vacuum CCD camera can be inserted in the object plane to observe the light distribution in the illumination beam path
- Due to its modular concept, the R&D ABIT can be flexibly upgraded to users requirements
- With the tool in operation our funded project ends at the end of 2012. Continuation may be supported by our offer, to supply tools for third parties studies at our side or prepare the tool to be used at any central.

R&D ABIT

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