Inband EUV Open Frame Resist Exposer TEUVL

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The first tool worldwide for exposing resists with inband EUV radiation (**T**EST **EUV L**ITHOGRAPHY TOOL) using a laboratory discharge source has been shipped by AIXUV to INFINEON in Erlangen in October 2002. The system uses the xenon emission from the discharge based EUV-Lamp. This radiation is filtered to about 4 % bandwidth ”inband” EUV by suppressing ultraviolet radiation with a beamline window of Zirkonium and by applying one reflection from a multilayer mirror. At the wafer plane a illumination homogeneity of better than 5 % is achieved even with a single pulse of the source. Twenty fields of 5 mm in diameter are exposed in parallel. The exposure rate is around 0.1 mJ / cm² per minute with the 50 Hz source. Dose values can be selected by absolute value.

Calibration was achieved by pre-calibrating the diodes and correcting with experience from exposures of the same resist at the system and at BESSY. Using three diodes as beam monitors close to the wafer plane and a PLC controlled shutter, gray-scale exposures with close-loop dose control is accomplished.

Some results from resist exposures will be presented by INFINEON. TEUVL has proven it’s longtime performance and mechanical stability by having printed 50 nm lines and spaces using a stencil mask even with about one hour of exposure.

Task / Demand Integrated | **Solution**

In-House resist exposure supplementing research at BESSY II beamline for the development of EUV resists with features:

Task / Demand Integrated	Solution
• Only expose with nearly in-band EUV radiation	• Spectral filter for EUV, VIS, outband
• 20 fields of 5 mm diameter exposed with different doses	• Field aperture with field shutters
• Exposing with pre-set doses	• In-line closed-loop dose control
• Results to be comparable with beamline at BESSY II	• Calibration of exposure doses
• Homogeneous illumination of the individual fields	• Open beam at sufficient distance
• Clean vacuum in exposing volume (detect outgasing)	• UHV-compatible design
• Compact, affordable device	• Discharge lamp, practical solutions
• Stability, reliability for >> 100 wafers	• Discharge "EUV-lamp"
• Clean-room compatible	• Steel housing; open for laminar flow
• Less than 2 hours for 20 fields	• Parallel exposure sufficient power
• Load-locking	• 3 chambers with separation valves

EUV-Resist Exposer System

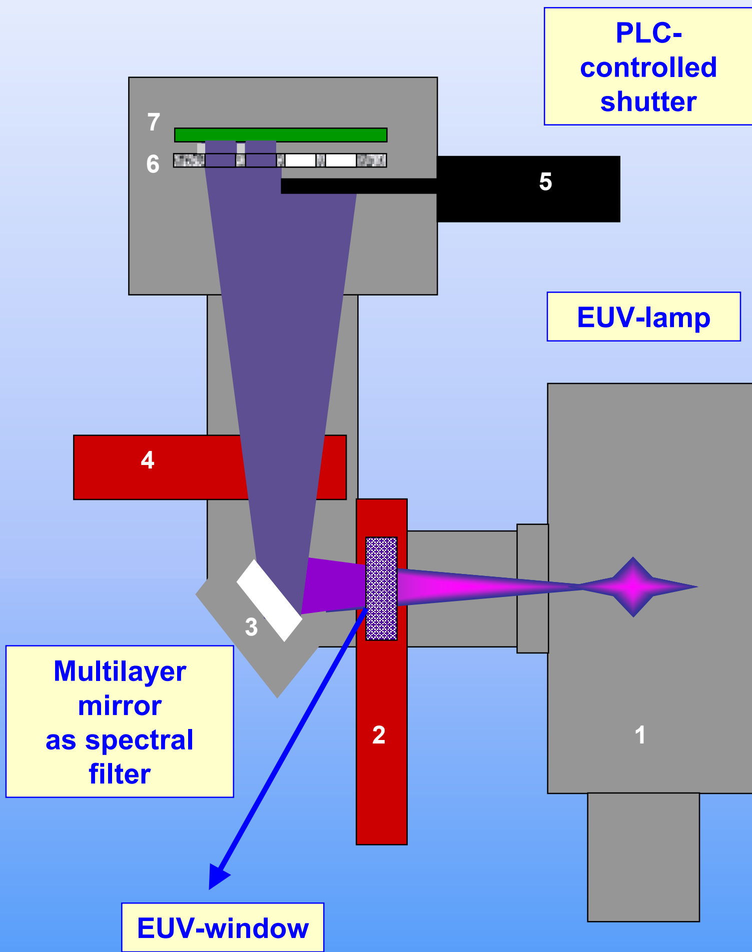
Designed as workbench tool

The system is constructed and designed for R&D clean-room operation.

Laminar flow open containment
Open set - up
Little mechanical movement
All steel vessels and beamlines
aluminum profiles

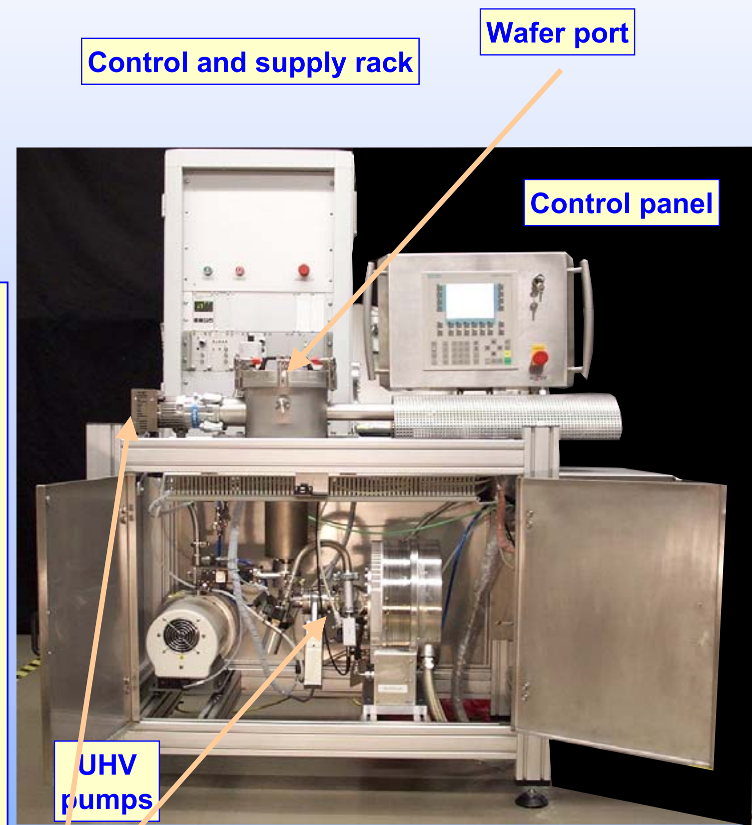
Control rack goes into gray room
Work bench in clean-room

Solution with EUV Lamp integrated into system



Recipe:

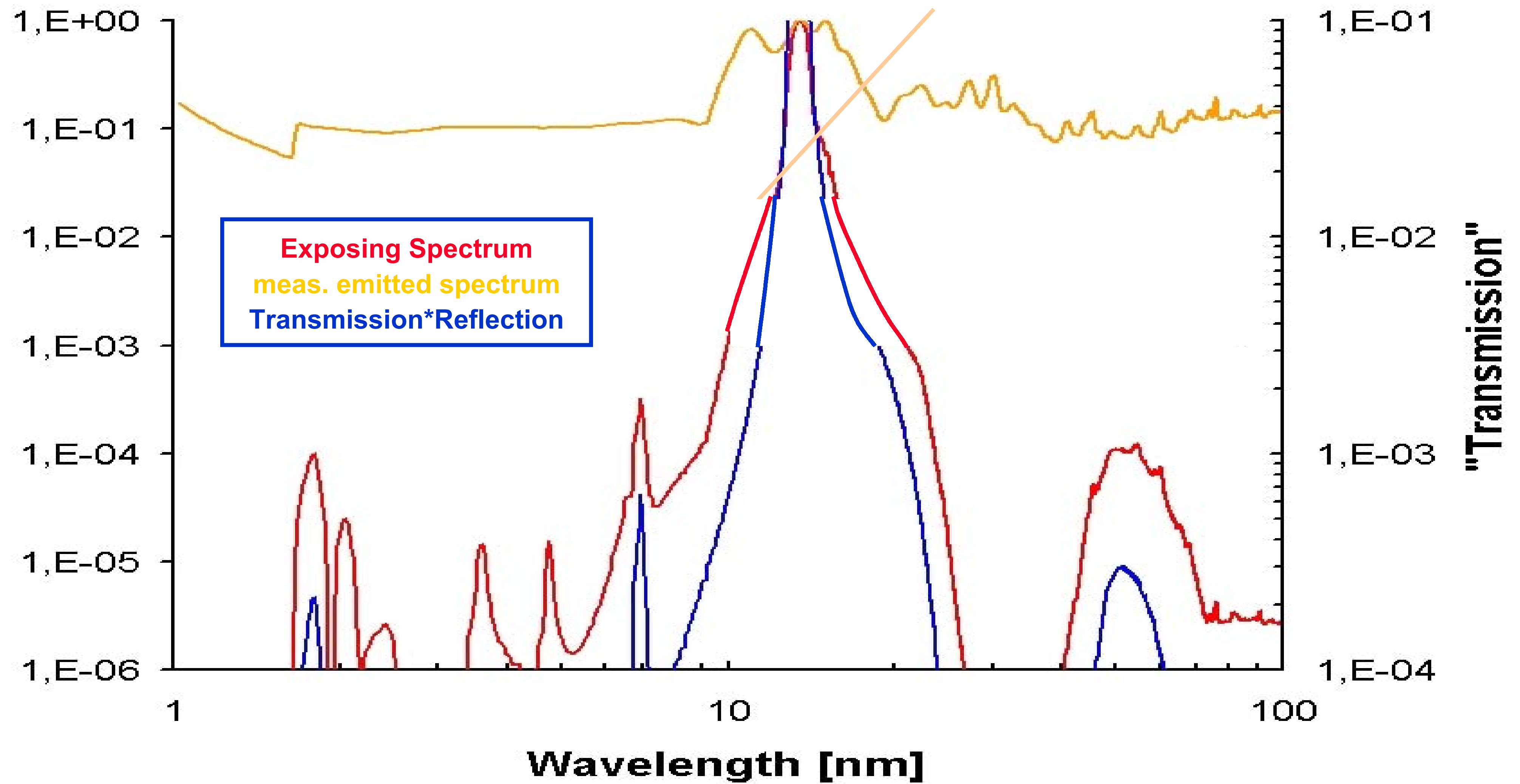
- Use available EUV-lamp (1) with long lifetime
- Expose all fields in parallel i.e. use source emission ($\Delta\Omega$, $\Delta\lambda$) most effectively (7)
- Use divergent light of point source at sufficient distance for homogeneity
- Separate source and application by window(2)
- Suppress UV and visible light by metal window (2)
- Select inband EUV by reflection from multilayer mirror(3).
- Keep mirror always in UHV(4)
- Measure impinging dose at wafer level for in-line closed loop dose control (6)
- Use single shutter for field control (5)



Convectively air cooled EUV-Lamp
Debris shielded by zirconium window
Spectrally filtered by EUV multilayer reflection
Automatic valves for shielding of mirror
Automatic easy wafer insertion
MTBF : > 10^8 pulses

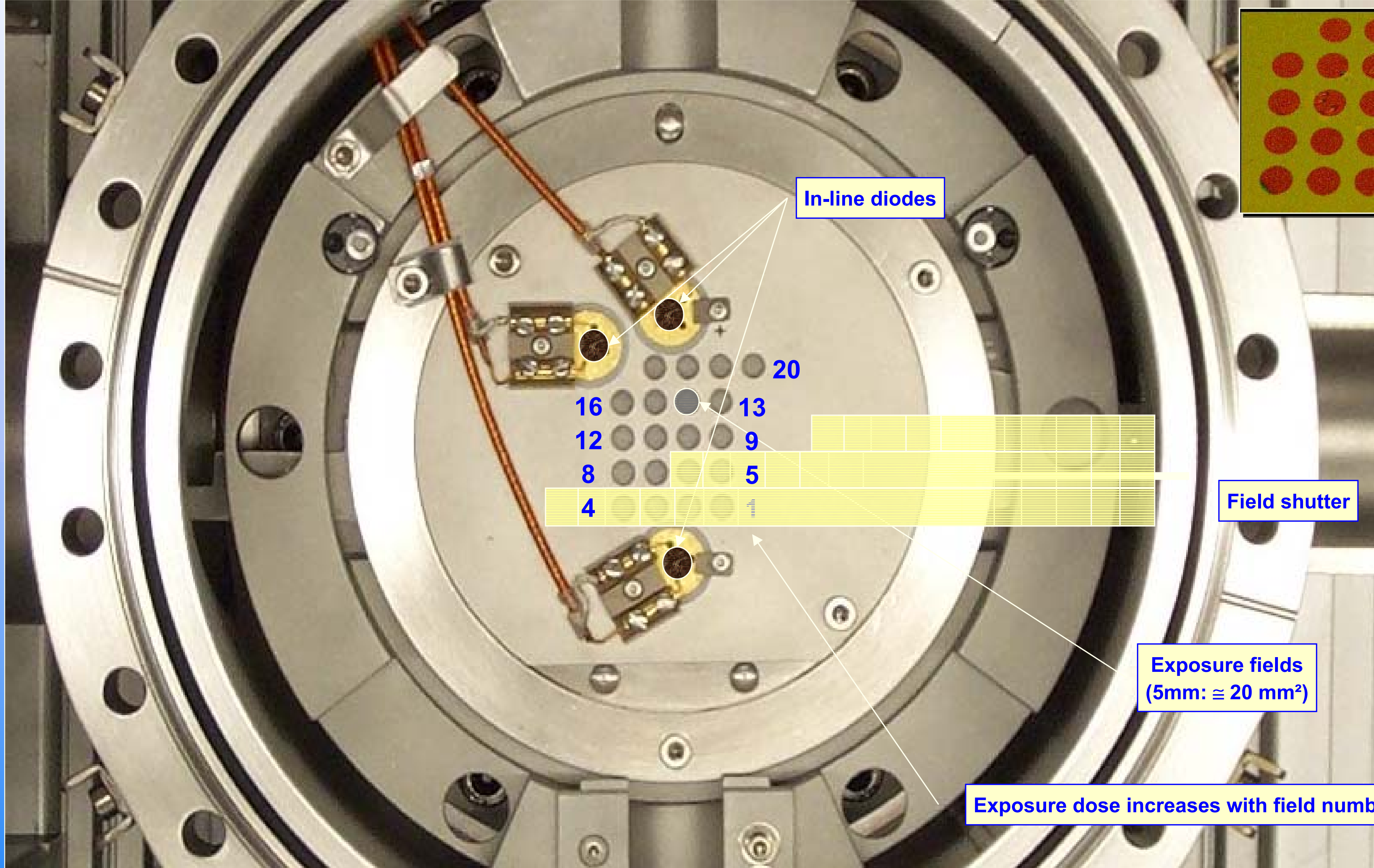
Dose Distribution Optimized for Grey-Scale Exposures

Effective out of band filter



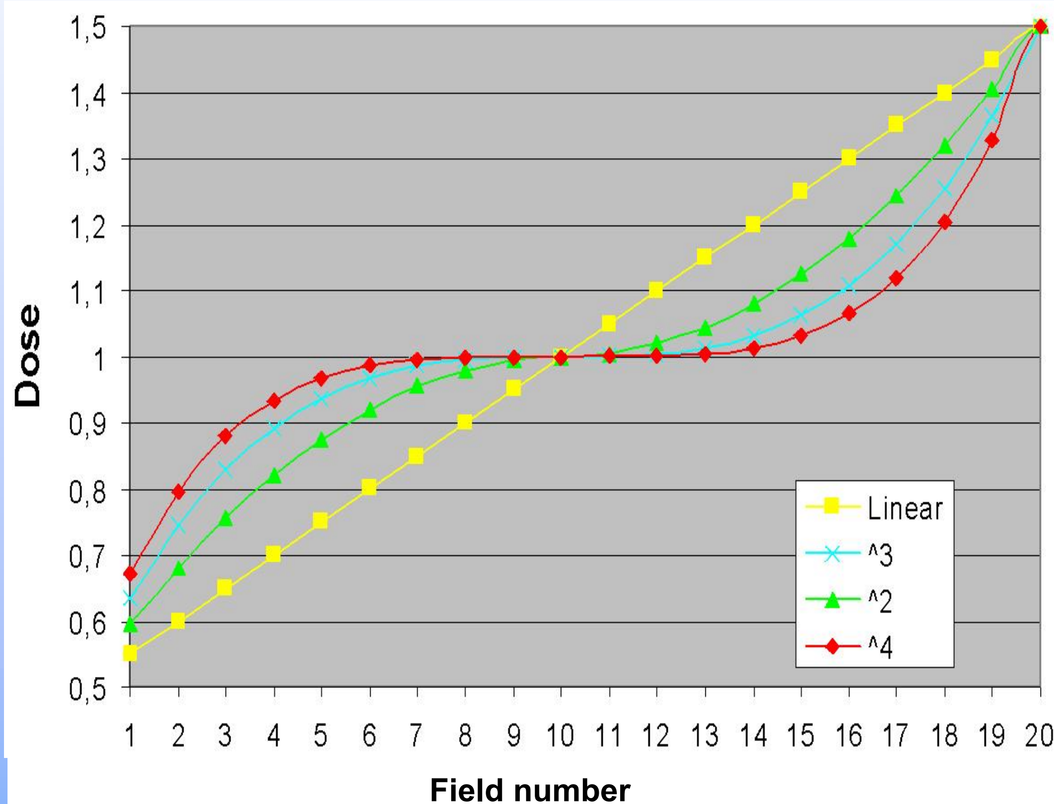
Transmission through zirconium window and reflection (45°) from multilayer is effective band pass filter (about 2*inband)

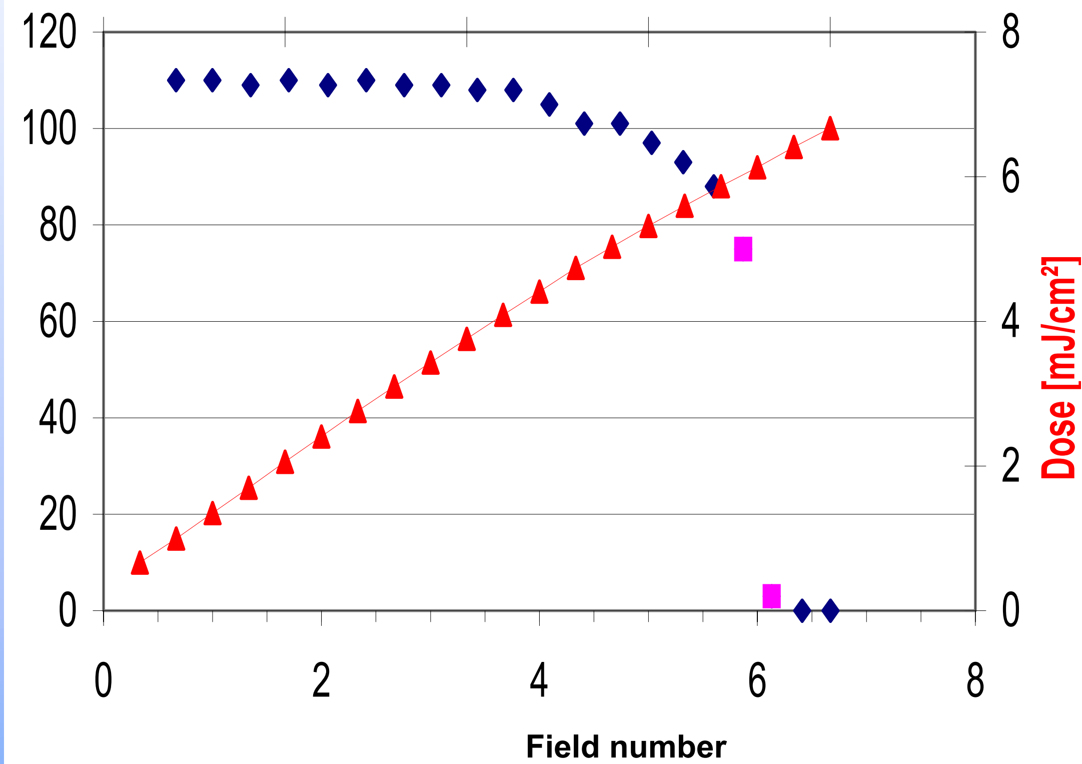
Aperture Mask System with Flux Measurement



Field Mask with 3 in-line diodes for flux/dose determination

Dose Distribution Optimized for Grey-Scale Exposures





First result: EUV dose-contrast curve

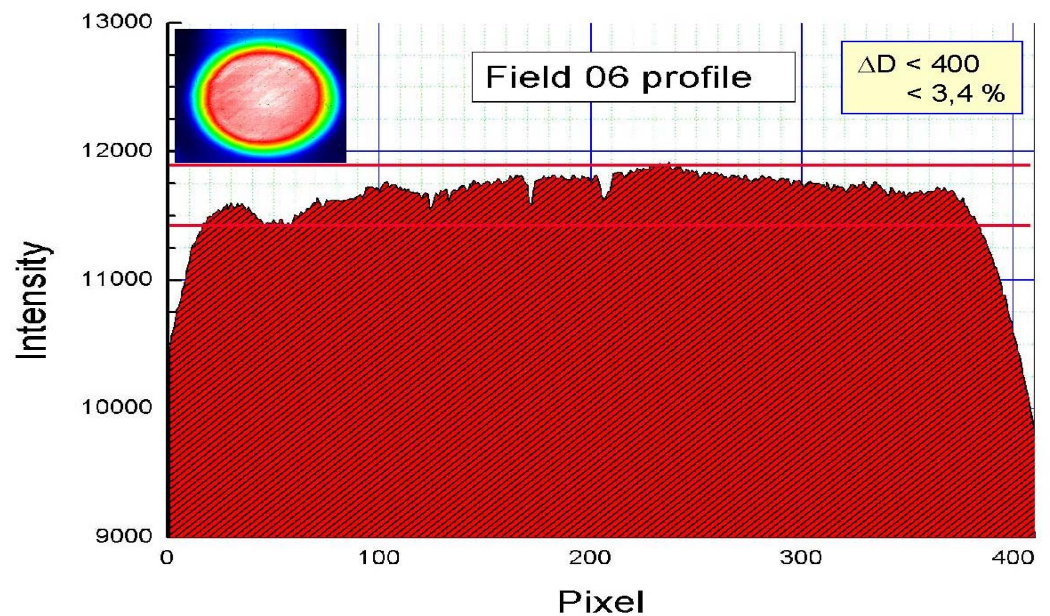
Dose distribution over fields is controlled by 3 parameters:

1.) "central dose", i.e. dose of field # 10
2.) bandwidth of dose distribution (i.e. 10% ... 100%)
3.) Power-law of distribution, allowing for concentrating more fields close to expected threshold dose.

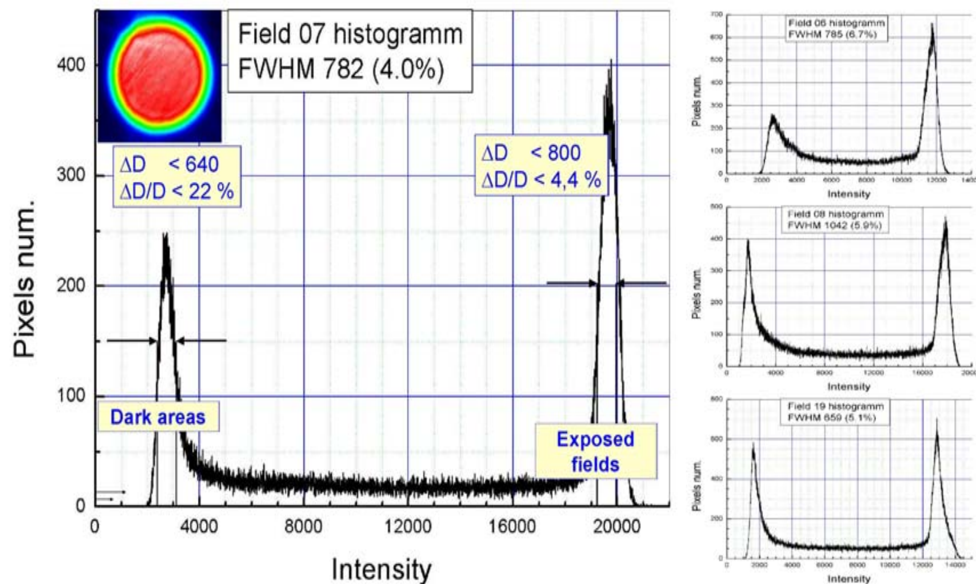
EUV-lamp with 300 mW/4 π sr inband allows for exposures of 5 mJ/cm² in less than one hour.
Power upgrades are available.

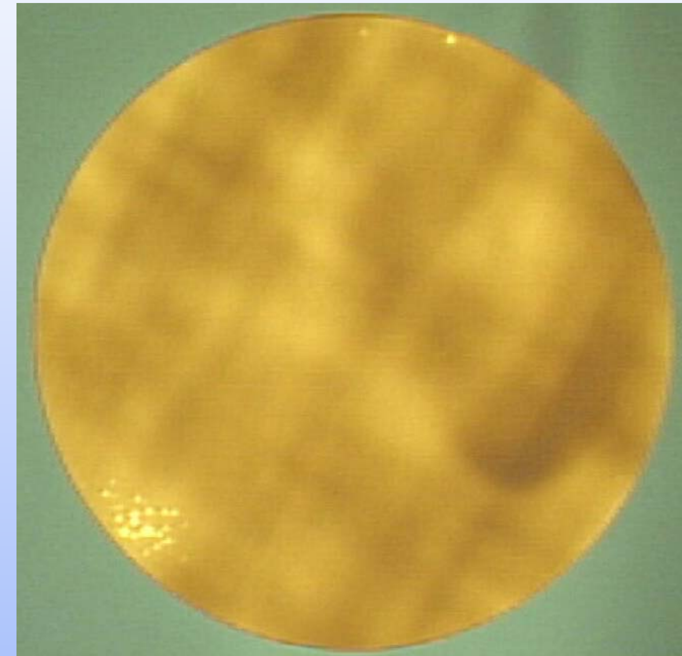
Calibration of dose measurement with diodes agrees well with BESSY II exposures.
(Checked with parallel exposures of the same resist.)

Field exposure is homogeneous



< 5 % RMS variation of dose of single field by single pulse determined with EUV-CCD.





Field with nearly dose to clear for steep and sensitive resist shows 1 % fluctuations due to support mesh on zirconium window

Single pulse CCD images where taken in exposure fields.

< 5 % RMS variation of dose within single field in one single pulse

Muore than 50.000 pulses should improve statistics.

Photon statistics in exposure fields prove homogeneous exposure

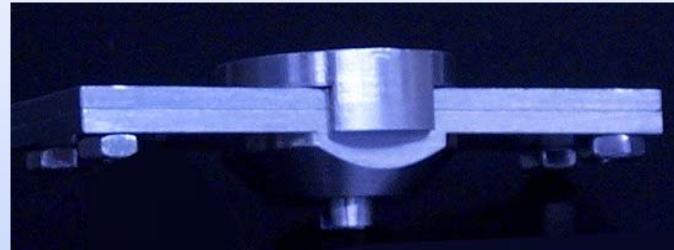
50 nm Lines and Spaces Contact Printed

Feasibility of proximity printing with TEUVL and mask insert demonstrated

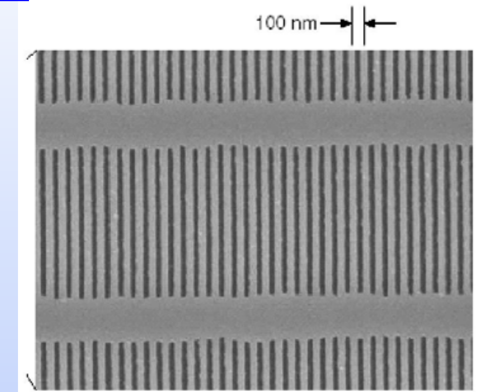
50 nm lines and spaces observed

Stability of better than 50 nm was achieved over 50 minutes exposure

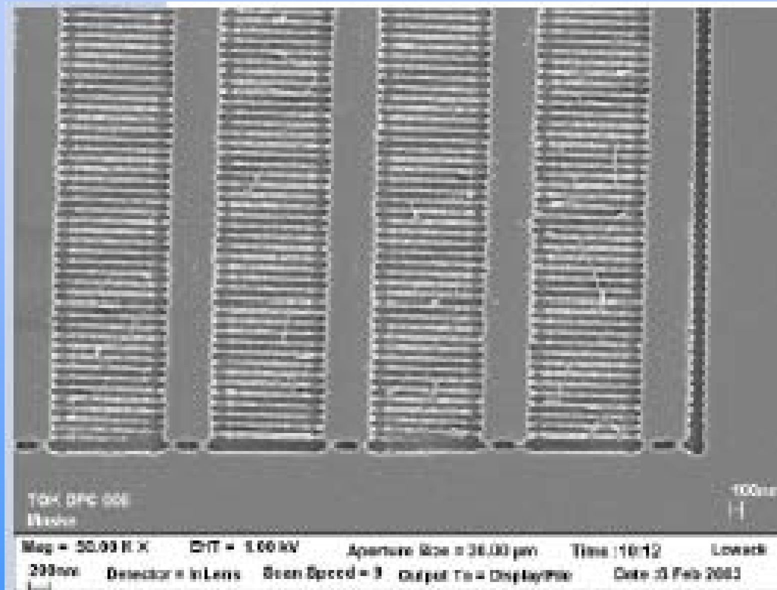
Distance control difficult (physical limit)



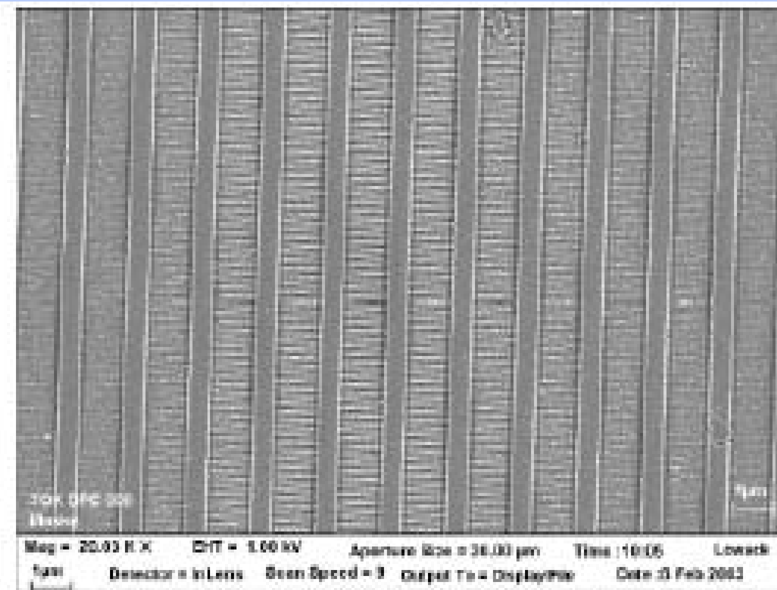
Contact mask insert into aperture plate



10.000 lines per mm
free-standing contact mask



Down to 50 nm L/S
Customer specific masks can be supplied (Elbows, single lines etc. from 500 nm down to 50 nm sizes).



Pattern transfer is diffraction limited.

Astoning result with Fresnel number $N_f \cong 0,5$ for 100 nm resist and D=0