Lithography Optics Division

Optics for EUV Lithography

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A collector module has been qualified and is used to test the illuminator at wavelength.

The early projection optics is in the qualification phase.

One illuminator has been qualified and the second is in process.

N. Harned et al: this conference

**Key specifications**

- \( \lambda \) 13.5 nm
- NA 0.25
- Resolution 50 nm
- Field 26x33 mm
- Magnification 4x
Illuminator

All mirrors have been fabricated and coated.

System fully assembled and aligned.

EUV qualification has been finished.
EUV qualification: hardware

@ λ  illuminator metrology tool

„reticle stage“ for metrology
Ring field measurement

Magenta lines: circles around optical axis

Stitching of 3 Images
EUV qualification: concept for field and pupil qualification

Setup for Field Qualification

Metrology-Reticile

Slit + Filter + EUV-Photodiode

Scanning field with slit EUV photodiode. Integration in y-direction.

Setup for Pupil Qualification

Camera

Lens

Vacuum window

Telecentricity Screen

Metrology Reticle, Pinhole

Reticle Stage
EUV qualification: Results (2)

Pupil: Telecentricity < 0.5%
Ellipticity < 10% (calculated value for Sn source)

measured uniformity at reticle plane < 2.5%
Status:

- all mirrors fabricated and coated
- assembly complete
- system metrology has been set up
- the POBox is in the qualification phase
System Metrology for POBox alignment/qualification has been set up

POBox test lens on system interferometer
Early POBox: Alignment Status

July 22: first light

248nm illumination (*converted by phosphor screen): image of the reticle mask in the wafer plane

Status today:
- POBox is in the final qualification phase

Performance prediction:
- 50 nm dense lines can be printed with the early POBox
Optics Technology (1): Fabrication of EUV mirrors

2D-isotropic PSD

Errors … causes …

figure → aberrations

MSFR → Flare, contrast
in field of view scattering

HSFR → reflectivity

Challenge:
reach about 0.2 nm rms for Figure, MSFR and HSFR simultaneously
Main challenge: flare reduction

Total integrated scatter \( TIS = (4\pi)^2 \left( \frac{rms_{surface}}{\lambda} \right)^2 \)

Due to the very small wavelength EUV imaging is sensitive to scatter !!!

\[ TIS \propto n_{mirrors} \cdot rms_{surface}^2 \]

Reduction of mid spatial frequency rms is essential to reduce the flare level
Main challenge: flare reduction

- Flare reduces overlap of process windows due to dose offsets.
- Proximity effects in dependence of the local reticle transmission.
- Sensitivity of CD to dose errors becomes larger.
- Largest impact of flare on isolated features on bright-field masks.
- Flare reduces overlap of process windows due to dose offsets.
Flare roadmap

![Flare Roadmap Graph]

- early POB
- AD 1
- AD 2
- production tool

Flare [%]
EUV mirror fabrication: Process development

Critical process step: Fine Figuring

Relative material removal: 100% is representative for reaching figure spec on alpha demo tool mirror

\[ \text{technology to reach MSFR of } \leq 0.2 \text{ nm rms on alpha tool mirrors has been established (16\% flare tool)} \]

\[ \text{Mirror for 16\% flare tool: M1 - 0.19 nm} \]
Learning curve – mid spatial frequency roughness

MSFR [nm rms] (evaluated over 4.6 decades)

- Test mirror
- Set 1
- Set 2
- Set 3

early POB mirrors

23% flare
16% flare
6% flare

production tool target

2000 2001 2002 2003 2004 2005 2006 2007 2008 2009
A complete set of alpha tool mirrors has been coated at FOM...

and Zeiss

Recent development at FOM

New capping layer:
- reflectance 68.5%
  comparable to uncapped multilayer

E. Louis et al: this conference
Summary

• alpha tool program is progressing:
  • illuminator
    • alignment and EUV qualification has been finished
  • POBox
    • all mirrors have been fabricated and coated
    • system metrology for the POBox is operational
    • the POBox has been assembled and is in the qualification phase
• technology development
  • 16% flare capability has been demonstrated on AD tool mirrors
  • new high reflectivity cap layer has been developed

EUV Optical Technology at Carl Zeiss SMT AG:
⇒ has reached α-tool specs
⇒ is progressing towards production tool capability
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