EUV Microscopy for Defect Inspection

Larissa Juschkin[1], Klaus Bergmann[2], Willi Neff[2], Rainer Lebert[3]
[1]RWTH Aachen, Chair for Technology of Optical Systems, [2]Fraunhofer Institute for Laser Technology, [3]AIXUV GmbH
all at Steinbachstr. 15, D-52074 Aachen, Germany
larissa.juschkin@ilt.fraunhofer.de, klaus.bergmann@ilt.fraunhofer.de, willi.neff@ilt.fraunhofer.de, lebert@aixuv.de

Introduction

General :

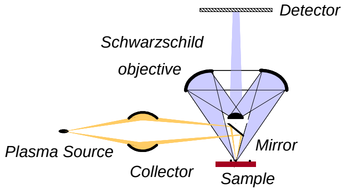
- at-wavelength metrology for defect inspection is mandatory for all printable defects (phase defects – buried defects in multilayer / amplitude defects – particles)
- compact EUV microscopes are usable for detection of all kind of defects in bright and dark field operation

Aim :

- key experiments on optimal layout for compact EUV microscope with discharge based light source

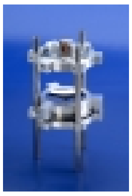
Experimental Set-up

Operation in reflection



Operation in transmission

Optical Components



Schwarzschild :

- magnification 21.3
- resolution <100 nm
- N.A. 0.2
- Si/Mo multilayer

Pixel size EUV-CCD 13 µm
⇒ only 1 µm resolution

⇒ second magnification step or a better digital detector required

Collector :

- reflectivity 80 %
- N.A. 0.16
- „magnification“ 0.25
- focal width 1 885 mm
- focal width 2 200 mm

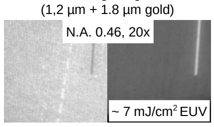
Converter Screen for Magnification

YAG:Ce converts EUV image into visible (4π)

visible objective with a preferably high N.A. for larger collection angle, possibly immersion

visible CCD

YAG:Ce scintillator
coated with a grating structure (1,2 µm + 1.8 µm gold)



visible light in reflection   EUV light in transmission

Light losses:	demo experiment	optimized
• scintillator conversion efficiency	~ 2,7 %	2,7 %
• collection efficiency of objective	~ 1,5 %	4,5 %
• magnification to CCD pixel size	~ 0,2 %	2%

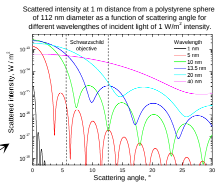
Theory of Defect Scattering

Scatter from isolated particulates

- $\lambda \gg a$ Rayleigh scattering

$$\frac{I_s}{I_i} = \frac{8\pi a^6}{\lambda^4 R^2}\left|\frac{n^2-1}{n^2+2}\right|^2 \left(1+\cos^2\theta\right)$$

- $\lambda \leq a$ no exact solution (exiting field amplitude and phase change as a function of material position). Mie-theory for scattering at spheres: $I_s = I_i \frac{[Sn(\theta)]^2}{k^2 R^2}$



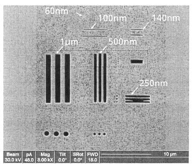
Scatter from a smooth sinusoidal surface

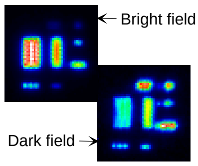
$$\sin\theta_n = \sin\theta_i + n f_g \lambda, \quad \ell = 1/f_g \qquad P_n \cong \left(\frac{2\pi a}{\lambda}\right)^2 \cos^2\theta_i$$

surface wavelength

Images of Transmission Mask

TEM Image   EUV Images

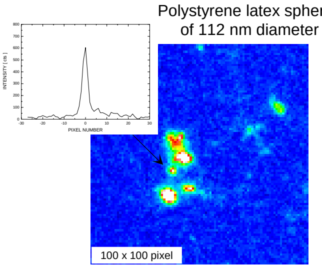


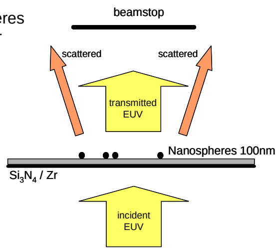


Small structures below 250 nm exhibit significantly higher contrast in EUV dark field images compared to 1 µm and 500 nm structures

Dark Field Image of Nanoparticles

Polystyrene latex spheres of 112 nm diameter





Summary

- Successful demonstration of defect detection with 0,1 mJ/cm² (single pulse operation)
- scan speed is limited by CCD read out
- for 5s CCD read out and 0,4 mm² image per pulse :

Scan Speed : 3 cm²/h

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