Recent progress in actinic lensless mask imaging tool at PSI

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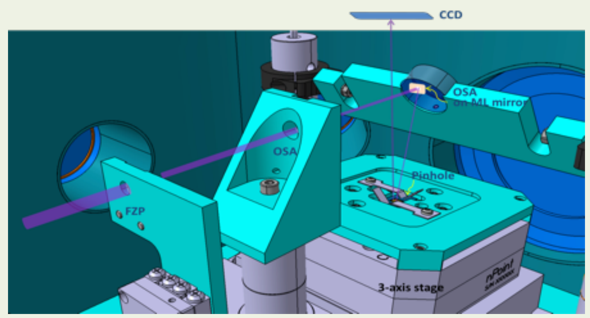
RESCAN: 'Reflective EUV Mask Scanning Lensless Imaging' is a promising solution for actinic EUV mask inspection using a scanning coherent diffraction imaging method

ABSTRACT

Actinic EUV mask inspection and review tools are still challenging for high volume manufacturing phase. For advanced mask evaluation we developed an actinic tool, which has been installed at the XIL-II beamline of Swiss Light Source (SLS). RESCAN is designed for imaging of blank and patterned EUV multilayers, with periodic, non-periodic or isolated defects, and it is capable of emulating the patterning conditions of scanners. We use ptychography for our computational lensless imaging system which is very sensitive to detect phase contrast image because ptychography is a super-resolution technique using phase retrieval algorithm from diffraction profiles of overlapping exposures. We show the imaging results of this tool through reconstructed aerial images of resolution test patterns on a multilayer mask using 0.1 (0.4/4) NA.
RESCAN has a great potential for cost effective actinic mask imaging without the limitations of EUV optics such as resolution and depth of focus (DOF)



RESCAN
Fully Reflective ptychographic imaging
Actinic review: λ = 13.5nm, 6 OAI
Navigation : Max. 100um X 100um
FOV: D= 5 – 10 um
Tunable NA: 0.25 - 0.4 (4X)

PRINCIPLE

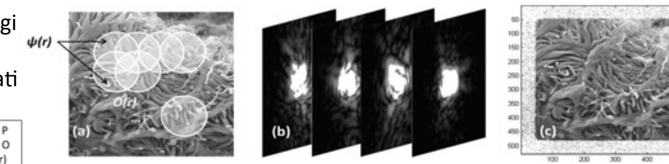
Ptychography is a scanning coherent diffractive imaging method.
Image of the sample can be reconstructed via iterative 'Fourier' re-transform calculations.

$$\psi_i(r) = P(r - r_i)\ O(r)$$

"probe" P
"object" O
vector (r)
exit wave (Ψ)

It is well established method for microscopy with visible light to hard X-ray as well as electrons.

Illustration of scanning method

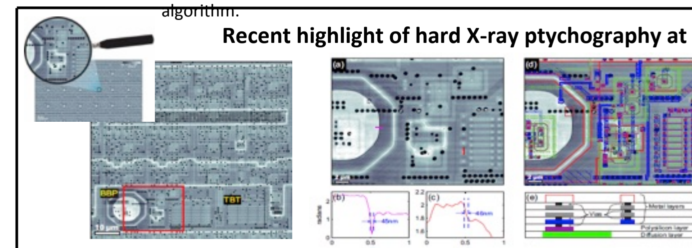


(a) The specimen is scanned with a compact illumination such that there is sufficient overlap between neighboring positions.
(b) For each illumination position a coherent diffraction pattern is recorded.
(c) Aerial images of the sample are reconstructed using ptychographic algorithm.

Advantages:

1. **Fully actinic !**
2. **Lensless imaging : No expensive optics**
3. **Resolution is not limited by optics**
4. **Large depth of focus**
5. **Both amplitude and phase are reconstructed.**
6. **Tunable wavelength and incident angle**
7. **3D tomography of surface on grazing angle.**
8. **No limit of field of view (FOV)**

Recent highlight of hard X-ray ptychography at PSI



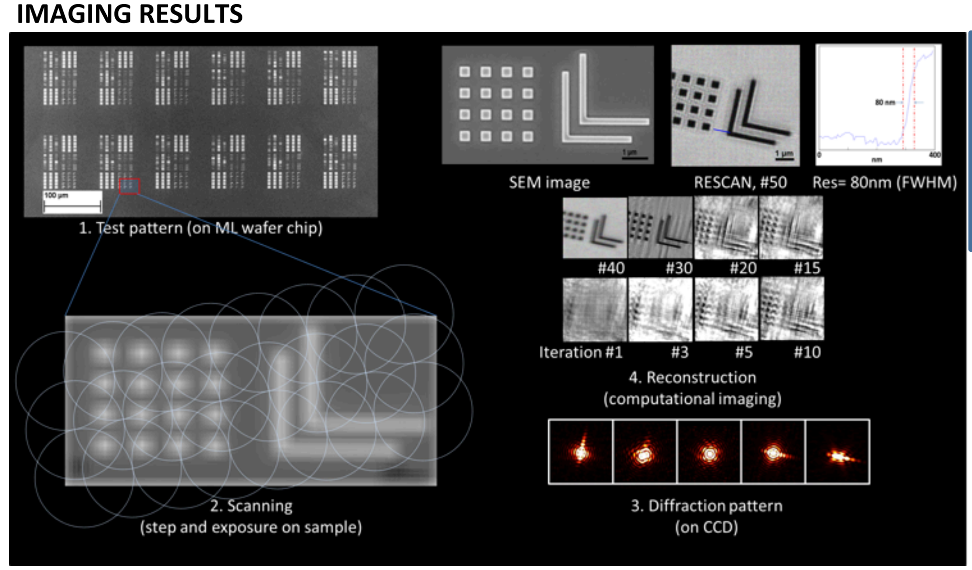
High throughput ptychography: Imaging 500 µm × 290 µm region of an integrated electronic circuit with 41 nm resolution. [1]

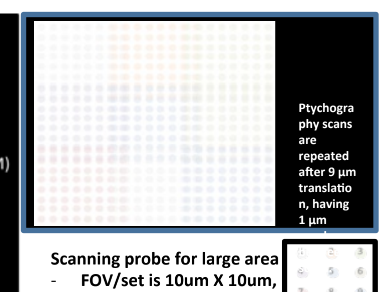
BEAMLINE SETUP & OPERATION

1. XIL-II: Stable undulator source, 2mm^2 light on FZP.
2. Fresnel zone plate (FZP, d=1mm, dr=500nm) and pinhole (d=5um) on SiN membrane as coherence control, bandwidth: 1% on sample
3. Order sorting aperture (OSA, d= 40um) on ML mirror as selecting 1st order diffraction
4. 3-axis sample stage: speed, 500msec/step, travel range : 100um X 100um
5. Raster scanning: (coarser scanning is optional)
6. FOV: annular illumination, d=5um
7. Exposure time: 50msec/single shot
8. Diffraction signal recording on CCD (PI-XO, pixel size: 20um, 1340X1300 pixel^2)

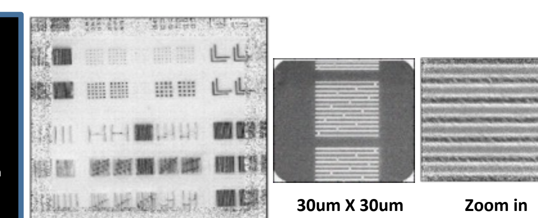
EUV-IL & RESCAN at XIL-II beamline

IMAGING RESULTS





Scanning probe for large area
- FOV/set is 10um X 10um,
- Raster scanning points for 50 µm × 50 µm FOV



Reconstructed image from 50 µm × 50 µm FOV

30um X 30um FOV RES 80nm

Zoom in 200nm hp L/S RES 80nm

CONCLUSIONS & OUTLOOK

We have developed RESCAN-I that is a new method for actinic mask review.
This work shows the potential of ptychographic imaging methods for high-resolution actinic mask inspection. We believe that the RESCAN can substantially contribute to the studies on mask defect identification and repair. With the development of stand-alone coherent EUV sources and further development of this method, ptychography can be a powerful method for the realization of actinic mask inspection tools with high resolution and throughput.

UPCOMING UPGRADE

RESCAN I+ : Modification for high NA up to 0.72(4X), Theoretical resolution limit: 6 nm

	RESCAN-I	RESCAN-I+
purpose	Feasibile test for fully reflective ptychographic imaging	Resolution enhancement
monochromatization	FZP & fixed pinhole on sample upstream	FZP & motorized pinhole stage / Grating mirror
illumination angle & λ	6° & 13.5nm	6°- 10° & 13.5nm – 6.5nm
max NA (4X), resolution	0.4, 20nm (on wafer)	0.72, 6nm (on wafer)
Detector	Vacuum CCD, fixed flange	In-vacuum CCD, rotatable stage

Reference

1. M. Guizar-Sicairos, et al. OPTICS EXPRESS 14859, (2014) DOI:10.1364/OE.22.014859

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