# The Energetiq EQ-10 EUV source for metrology --Review of recent data

# **ENERGETIQ**

Stephen F. Horne, Matthew J. Partlow, Deborah S. Gustafson, Matthew M. Besen, . Donald K. Smith, Paul A. Blackborow Energetiq Technology, Inc.



### EQ-10



# EQ-10SXR

Soft X-Ray Source for Water Window Microscopy and 7nm R&D

### EQ-10HP

High-Brightness, 20Watt EUV Source for Metrology & Testing

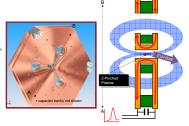
# FO-10HR

High Repetition-Rate FUV Source for Accelerated Optics Testing

### BACKGROUND

Energetiq's EQ-10 Series of Electrodeless Z-Pinch EUV sources are widely used around the world as reliable sources of Extreme Ultraviolet (and Soft X-Ray) light. They have evolved in three directions since the introduction of the original 10 Watt, 1.9kHz, 13.5nm source in 2005.

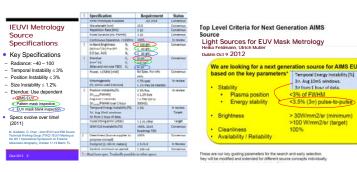
- Higher Repetition Rate (10kHz) for accelerated testing of EUV optical components (EQ10-HR)
- Shorter Wavelength (2.88nm) for Water-Window Biological Imaging
- Higher Brightness/Higher Power (20W) for Actinic Mask Inspection



# **Evolution of Metrology Specifications**

•Emulate scanner optics, on-wafer image creation using CCD

- •Resist-coated wafer is a much more forgiving target! •Mask Blank Inspection
- •Requirements unrelated to Scanner optics (Easier task)
- •Actinic Patterned Mask Inspection
- •Requires highest source performance
- •EUV production will probably begin without actinic tool (using upgrades of existing tools)



2011 2012

# 6.7nm Electrodeless Z-Pinch Using Neon

EQ-10SXR Soft X-Ray Source Delivers Photons Reliably at 2.88nm: Modify for use at 6.7nm

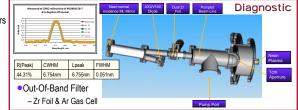
lon	Observed λ (nm)	Rel. Int. <u>(?)</u>	(s <sup>-1</sup> )	A CC	<i>E<sub>i</sub></i> (eV)	E <sub>k</sub> (eV)	Configurations		
Ne VIII	6.5822	1000	3.50e+10	В	15.88881	[204.2389]	1s22p	ŀ	1 <i>s</i> <sup>2</sup> 5 <i>d</i>
Ne VIII	6.5895	1300 <u>*</u>	4.19e+10	В	16.09330	[204.2429]	1 <i>s</i> <sup>2</sup> 2 <i>p</i>	-	1 <i>s</i> <sup>2</sup> 5 <i>d</i>
Ne VIII	6.5895	1300 <u>*</u>	6.97e+09	В	16.09330	[204.2389]	1 <i>s</i> <sup>2</sup> 2 <i>p</i>	-	1 <i>s</i> <sup>2</sup> 5 <i>d</i>
Ne VIII	6.7382	1500 <u>*</u>	3.97e+10	В	0.0000	[184.0070]	1 <i>s</i> <sup>2</sup> 2 <i>s</i>	-	1 <i>s</i> <sup>2</sup> 4 <i>p</i>
Ne VIII	6.7382	1500 <u>*</u>	3.97e+10	В	0.0000	[183.9816]	1 <i>s</i> <sup>2</sup> 2 <i>s</i>	-	1 <i>s</i> <sup>2</sup> 4 <i>p</i>

# Gas Selection

- NIST spectral database used
- Search lines with high relative intensity
  - Only gas which appears is Neon

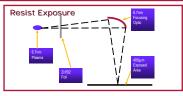
# Operating Parameters

- -430 V, 1100 Hz,
  - -5.5 kW DC power -400 mT pressure
- Output Power
- -~70mWatts



Practical Integration into Resist Sensitivity Measurement Tool:

- Using ZrB2 foil eliminates need for Argon out-of-band Filter
- Focusing optic at 6.7nm increases power density on wafer
- more than 100X <30sec/mJ exposure time at wafer



### Image analysis - brightness calculation, positional stability

Locate the "center" via center-of-mass or fitting Set up a radial data structure with 3 bins per radial location

For each pixel in the image Calculate radius of the pixel. Use that as an index into the structure.

At that index, add in the radius Increment the counter for this radial bin

When all pixels have been scanned: Calculate average radius and average counts..



 $\vec{R}_j = \vec{R}s_j/\vec{N}_j$  $\vec{C}_j = \vec{C}s_j/\vec{N}_j$ 

# Position stability – simple algorithm improvement

Usual analysis - acquire a series of images, then

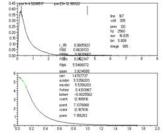
Find peak pixel

→ ??

Calculate centroid -- region centered on peak pixel. ue – Poisson photon distribution -> peak pixel not constant.

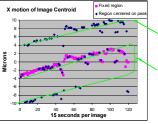
Motion of peak by a single pixel introduces non-physical jitter.

Instead – use a fixed region for all the images Result – previously reported variability, ~15 microns (3 $\sigma$ )
Requirement (assuming 400 micron fwhm) 12 microns, (3 $\sigma$ )
New algorithm – < 6 microns



diamond

ZEHSS



Drift due to camera motion (since corrected) Old algorithm – 22 microns (3σ) New algorithm – < 6 microns (3σ) Typical results from improved metrology -- < 3 microns (3σ) Pixel size ~ 15 microns; offset effect is about 0.5 pixel. Edge effect due to shift of calculational grid.

## Water Window Microscopy at 2.88 nm



Preliminary Laboratory-source Results (Diamond) courtesy Liz Duke and Colleagues

Samples prepared by: Raffa Carzaniga, Charlotte Melia, Lucy Collinson (London Research Institute, Cancer Research UK)

Nuclear / perinuclear region of a HeLa cell



