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Publication Date

2011-05-31

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We present the potential capabilities of a low-cost next generation EUV mask-imaging microscope, based on the proven optical principle of the SEMATECH Berkeley Actinic Inspection Tool (AIT), but surpassing it in every performance metric. The new tool design would enable research on multiple generations of EUV lithography technology, down to 8-nm or beyond, reaching to the year 2025's design rules.

Owing to the wavelength-specific reflective properties of EUV reticles, imaging with EUV light is the only faithful way to understand the physical response of defects, repairs, and pattern optical proximity corrections. The wavelength-specific properties limit the effectiveness of all non-EUV inspection technologies, and the differences between EUV and non-EUV measurement technologies are likely to increase in future nodes. Therefore, the prolonged unavailability of an EUV microscopy tool could hamstring the commercialization of EUV lithography, and impede research into future nodes.

As a high-magnification all-EUV Fresnel zoneplate microscope, the AIT has been in the vanguard of high-resolution EUV mask imaging for several years. The AIT's measurement of mask architectures, blank and pattern defect imaging, defect smoothing and printability, and recently, direct, quantitative aerial image phase measurement, has expanded our collective understanding of EUV masks and shaped the course of current mask development. A new tool could greatly surpass the capabilities of the AIT by overcoming many of its current limitations.

Our studies show that in a new system design, the photon efficiency can be improved by 200x by streamlining the illuminator (removing two mirrors) and reengineering the nanofabricated zoneplate structure. Combined with an xyz mask stage and vibration isolation for nm-scale stability, the system throughput could be increased relative to the AIT, from two to ten through-focus measurement series per hour, with 2x higher signal-to-noise ratio and improved illumination uniformity. A lossless, custom-coherence illuminator, implemented with scanning mirrors, can mimic arbitrary, future steppers and prototypes. The illuminator design can accommodate an adjustable angle of illumination from 6 to 9° enabling 4x-NA values up to 0.625. An array of zoneplate lenses, similar to the current AIT, gives the flexibility to implement various discrete NA values, with a low-magnification mode for rapid pattern navigation.

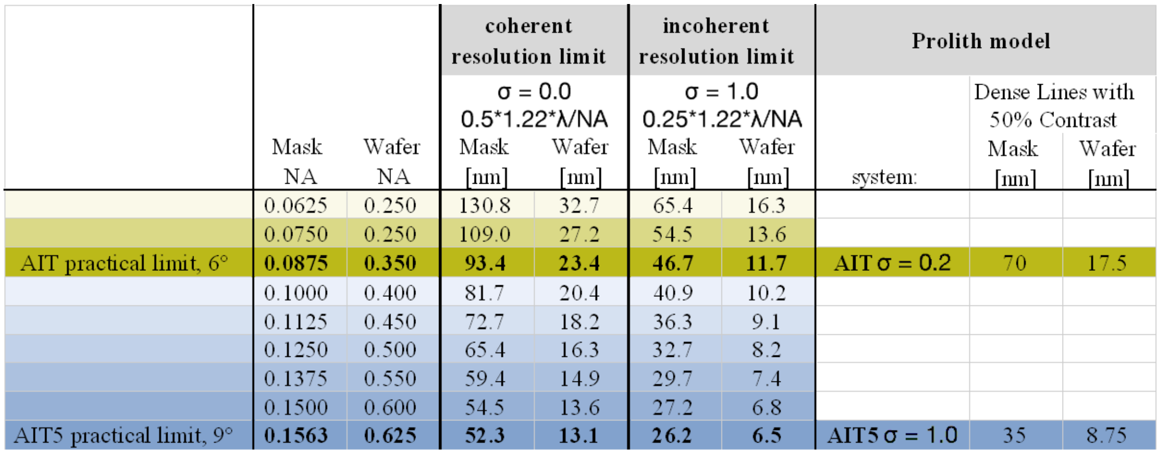
We will present detailed analysis of the NA and focal length dependence of the imaging field of view, showing that Strehl ratios above 0.95 and CD uniformity measurements with 3 sigma values in the 2-6 nm range are possible across a circular, aberration-corrected sweet-spot several microns diameter. Relative to high-magnification reflective lenses, zoneplates are simple to use and align, and they can be produced inexpensively, with diffraction-limited quality and demonstrated flare below 3%. Despite narrow illumination bandwidth requirements, a zoneplate-based system could be used with emerging coherent EUV sources, with some design trade-offs.

We believe that an EUV aerial image microscope system such as this could be brought online in 2012, well in advance of commercial tool availability, and would be ready for advanced research on future EUV lithography generations.

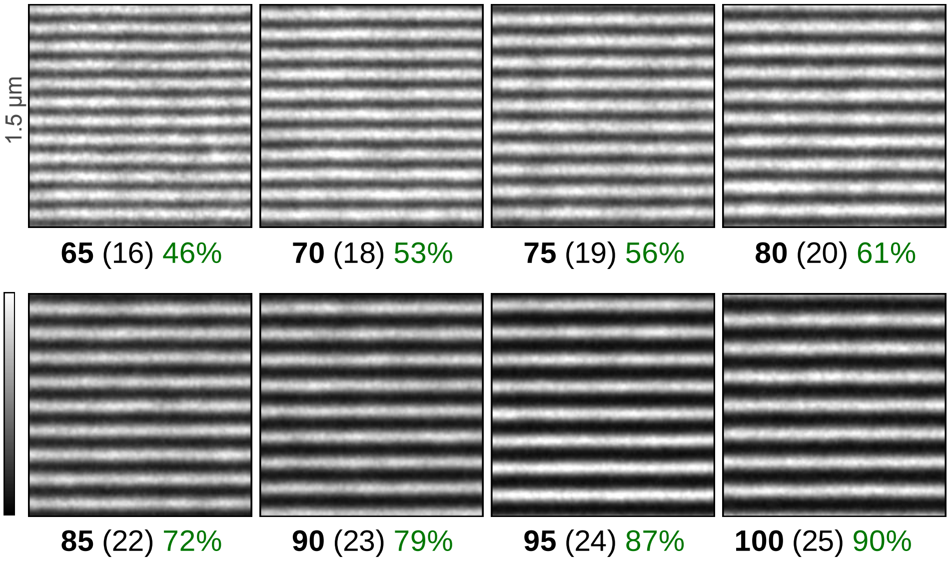
This work was performed under the auspices of the U.S. Department of Energy by University of California Lawrence Berkeley National Laboratory. This work was funded by SEMATECH through the U.S. Department of Energy under Contract No. DE-AC02-05CH11231.

Key Words: Extreme ultraviolet lithography, mask imaging, reticle, line width roughness, actinic inspection

Table 1. Theoretical imaging resolutions of the AIT (yellow) and the proposed new system, called AIT5 (blue) for different NA and σ values. Dense lines reach 50% contrast at the given half-pitch values. The Prolith model used a circular, unobstructed pupil and a 3% flare level.



			coherent resolution limit		incoherent resolution limit		Prolith model		
			σ = 0.0 0.5*1.22*λ/NA		σ = 1.0 0.25*1.22*λ/NA			Dense Lines with 50% Contrast	
	Mask NA	Wafer NA	Mask [nm]	Wafer [nm]	Mask [nm]	Wafer [nm]	system:	Mask [nm]	Wafer [nm]
	0.0625	0.250	130.8	32.7	65.4	16.3			
	0.0750	0.250	109.0	27.2	54.5	13.6			
AIT practical limit, 6°	**0.0875**	**0.350**	**93.4**	**23.4**	**46.7**	**11.7**	AIT σ = 0.2	70	17.5
	0.1000	0.400	81.7	20.4	40.9	10.2			
	0.1125	0.450	72.7	18.2	36.3	9.1			
	0.1250	0.500	65.4	16.3	32.7	8.2			
	0.1375	0.550	59.4	14.9	29.7	7.4			
	0.1500	0.600	54.5	13.6	27.2	6.8			
AIT5 practical limit, 9°	**0.1563**	**0.625**	**52.3**	**13.1**	**26.2**	**6.5**	AIT5 σ = 1.0	35	8.75



65 (16) 46% **70** (18) 53% **75** (19) 56% **80** (20) 61%

85 (22) 72% **90** (23) 79% **95** (24) 87% **100** (25) 90%

Figure 1. Aerial images recorded by the AIT show the line-imaging performance of the current system at a 4× NA value of 0.35. Below each image, the mask CD (bold) and the 4× equivalent wafer CD value (in parentheses) are given. The measured contrast is given in green. These results show that the current design of the AIT can achieve 50% contrast for mask CD values below 70 nm, validating the performance predictions of the AIT5 given in Table 1.

DISCLAIMER