Lawrence Berkeley National Laboratory
Lawrence Berkeley National Laboratory

Title
Microfield exposure tool enables advances in EUV lithography development

Permalink
https://escholarship.org/uc/item/7fb3232c

Author
Naulleau, Patrick

Publication Date
2009-10-30

Peer reviewed

eScholarship.org Powered by the California Digital Library
University of California

Microfield exposure tool enables advances in EUV lithography development

Patrick Naulleau, Lawrence Berkeley National Laboratory

This work was supported by the Director, Office of Science, Office of Basic Energy Sciences, of the US Department of Energy under Contract No. DE-AC02-05CH11231.

Headline: Microfield exposure tool enables advances in EUV lithography development

Summary: With demonstrated resist resolution of 20 nm half pitch, the SEMATECH Berkeley EUV microfield exposure tool continues to push crucial advances in the areas of EUV resists and masks.

The ever progressing shrink in computer chip feature sizes has been fueled over the years by a continual reduction in the wavelength of light used to pattern the chips. Recently, this trend has been threatened by unavailability of lens materials suitable for wavelengths shorter than 193 nm. To circumvent this roadblock, a reflective technology utilizing a significantly shorter extreme ultraviolet (EUV) wavelength (13.5 nm) has been under development for the past decade. The dramatic wavelength shrink was required to compensate for optical design limitations intrinsic in mirror-based systems compared to refractive lens systems. With this significant reduction in wavelength comes a variety of new challenges including developing sources of adequate power, photoresists with suitable resolution, sensitivity, and line-edge roughness characteristics, as well as the fabrication of reflection masks with zero defects.

While source development can proceed in the absence of available exposure tools, in order for progress to be made in the areas of resists and masks it is crucial to have access to advanced exposure tools with resolutions equal to or better than that expected from initial production tools. These advanced development tools, however, need not be full field tools. Also, implementing such tools at synchrotron facilities allows them to be developed independent of the availability of reliable stand-alone EUV sources. One such tool is the SEMATECH Berkeley microfield exposure tool (MET) [1].

The most unique attribute of the SEMATECH Berkeley MET is its use of a custom-coherence illuminator [2] made possible by its implementation on a synchrotron beamline [3]. With only conventional illumination and conventional binary masks, the resolution limit of the 0.3-NA optic is approximately 25 nm, however, with EUV not expected in production before the 22-nm half pitch node even finer resolution capabilities are now required from development tools. The SEMATECH Berkeley MET's custom-coherence illuminator allows it to be used with aggressive modified illumination enabling k_1 factors as low as 0.25. Noting that the lithographic resolution of an exposure tool is defined as $k_1\lambda/NA$, yielding an ultimate resolution limit of 11 nm.

To achieve sub-20-nm aerial-image resolution while avoiding forbidden pitches on Manhattan-geometry features with the centrally-obscured MET optic [4], a 45-degree oriented dipole pupil fill is used. Figure 1 shows the computed aerial-image contrast as a function of half pitch for a dipole pupil fill optimized to print down to the 19-nm half pitch level. This is achieved with relatively uniform performance at larger dimensions. Using this illumination, printing down to the 20-nm half pitch level has been demonstrated in chemically amplified resists as shown in Fig. 2 [4, 5].

The SEMATECH Berkeley MET tool plays a crucial role in the advancement of EUV resists. The unique programmable coherence properties of this tool enable it to achieve higher resolution than other EUV projection tools. As presented here, over the past year the tool has been used to demonstrate resist resolutions of 20 half pitch. Although not discussed here, because the Berkeley MET tool is a true projection lithography tool, it also plays a crucial role in advanced EUV mask research. Examples of the work done in this area include defect printability, mask architecture, and phase shift masks.

The author is greatly indebted to Warren Montgomery of SEMATECH for expert support of the MET project. Special thanks are also due to Chawon Koh of SEMATECH for resist, process, and metrology support. The author also acknowledges the entire CXRO team for development and operation of the EUV exposure tool. This work was funded by SEMATECH and performed at Lawrence Berkeley National Laboratory using the SEMATECH MET exposure facility at the Advanced Light Source. LBNL is operated under the auspices of the Director, Office of Science, Office of Basic Energy Science, of the US Department of Energy. Supported by the U.S. Department of Energy under Contract No. DE-AC02-05CH11231.

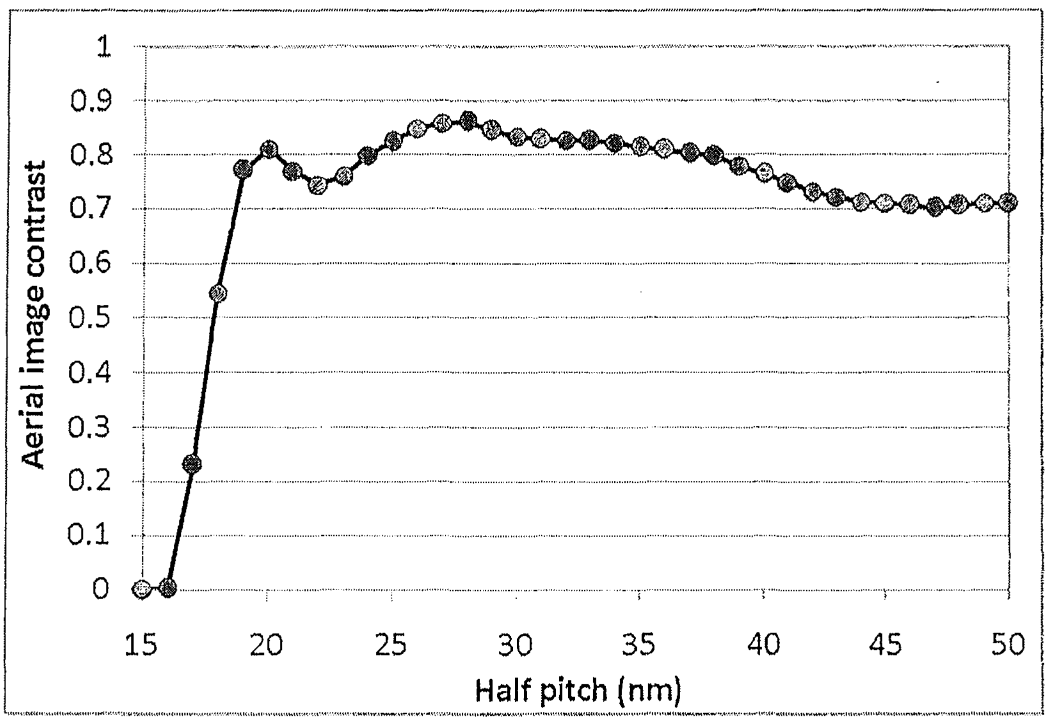

Fig. 1. Computed aerial-image contrast for the SEMATECH Berkeley MET using modified illumination (dipole, pole radius $\sigma = 0.1$, pole offset $\sigma = 0.57$, pole orientation = 45°.

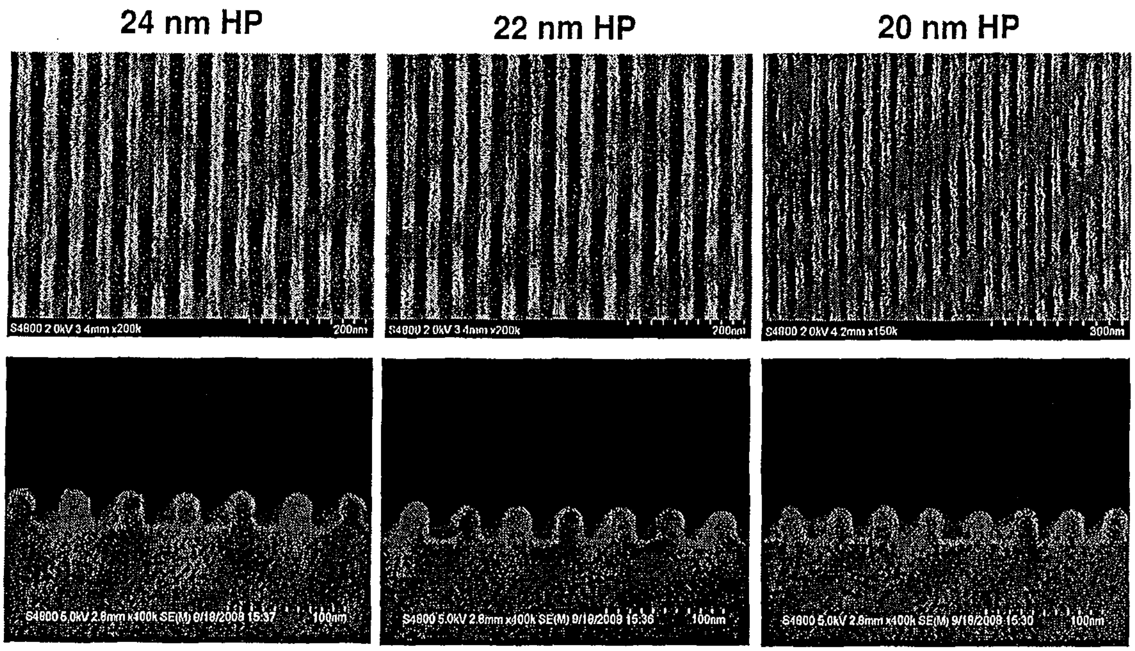

Fig. 2. Imaging results from a chemically amplified resist with a sensitivity of 15.2 mJ/cm^2.

References:

1. P. Naulleau, *et al.*, "Status of EUV micro-exposure capabilities at the ALS using the 0.3-NA MET optic," Proc. SPIE **5374**, 881-891 (2004).
2. P. Naulleau, K. Goldberg, P. Batson, J. Bokor, P. Denham, and S. Rekawa, "A Fourier-synthesis custom-coherence illuminator for EUV microfield lithography," Appl. Opt. **42**, 820-826 (2003).
3. D. Attwood, G. Sommargren, R. Beguiristain, K. Nguyen, J. Bokor, N. Ceglio, K. Jackson, M. Koike, and J. Underwood, "Undulator radiation for at-wavelength interferometry of optics for extreme-ultraviolet lithography," Appl. Opt. **32**, 7022-7031 (1993)
4. P. Naulleau, C. Anderson,a J. Chiu, P. Denham, S. George, K. Goldberg, M. Goldstein, B. Hoef, R. Hudyma, G. Jones, C. Koh, B. La Fontaine, A. Ma, W. Montgomery, D. Niakoula, J. Park, T. Wallow, and S. Wurm, "22-nm half-pitch extreme ultraviolet node development at the SEMATECH Berkeley microfield exposure tool," Proceedings of 34th International Conference on Micro and Nano Engineering 2008, Athens Greece, September 15-18, 2008..
5. P. Naulleau, C. Anderson, J. Chiu, K. Dean, P. Denham, S. George, K. Goldberg, B. Hoef, G. Jones, C. Koh, B. La Fontaine, A. Ma, W. Montgomery, D. Niakoula, J. Park, Tom Wallow, Stefan Wurm, "Latest results from the SEMATECH Berkeley extreme ultraviolet microfield exposure tool," J. Vac. Sci. & Technol. B **27**, 66-70 (2009).