EUV LITHOGRAPHY PUBLICATIONS

IACOPO MOCHI

Inverse chronological order

[1] Kenneth A. Goldberg, Markus P. Benk, Antoine Wojdyla, Iacopo Mochi, Senajith B. Rekawa, Arnaud P. Allezy, Michael R. Dickinson, Carl W. Cork, Weilun Chao, Daniel J. Zehm, James B. Macdougall, Patrick P. Naulleau, and Anne Rudack. "Actinic mask imaging: recent results and future directions from the SHARP EUV microscope". In: *Proc. SPIE 9048, Extreme Ultraviolet (EUV) Lithography V*. Vol. 9048. 2014. DOI: 10.1117/12.2048364. URL: http://dx.doi.org/10.1117/12.2048364.

[2] Markus P. Benk, Kenneth A. Goldberg, Iacopo Mochi, Weilun Chao, and Erik H. Anderson. "Increased depth of field through wave-front coding: using an off-axis zone plate lens with cubic phase modulation in an EUV microscope". In: *Proc. SPIE 8880, Photomask Technology 2013*. Vol. 8880. 2013. DOI: 10.1117/12.2025954. URL: http://dx.doi.org/10.1117/12.2025954.

[3] Rene A. Claus, Iacopo Mochi, Markus P. Benk, Kenneth A. Goldberg, Andrew R. Neureuther, and Patrick P. Naulleau. "Recovering effective amplitude and phase roughness of EUV masks". In: *Proc. SPIE 8880, Photomask Technology 2013*. Vol. 8880. 2013. DOI: 10.1117/12.2027828. URL: http://dx.doi.org/10.1117/12.2027828.

[4] Kenneth A. Goldberg et al. "Commissioning an EUV mask microscope for lithography generations reaching 8 nm". In: *Proc. SPIE 8679, Extreme Ultraviolet (EUV) Lithography IV*. Vol. 8679. 2013. DOI: 10.1117/12.2011688. URL: http://dx.doi.org/10.1117/12.2011688.

[5] Kenneth A. Goldberg et al. "The SEMATECH high-NA actinic reticle review project (SHARP) EUV mask-imaging microscope". In: vol. 8880. 2013. DOI: 10.1117/12.2026496. URL: http://dx.doi.org/10.1117/12.2026496.

[6] Iacopo Mochi, Kenneth A. Goldberg, Markus P. Benk, and Patrick P. Naulleau. "Pupil shaping and coherence control in an EUV mask-imaging microscope". In: *Proc. SPIE 8880, Photomask Technology 2013*. Vol. 8880. 2013. DOI: 10.1117/12.2026498. URL: http://dx.doi.org/10.1117/12.2026498.

[7] Lei Sun, Sudhar Raghunathan, Vibhu Jindal, Eric Gullikson, Pawitter Mangat, Iacopo Mochi, Kenneth A. Goldberg, Markus P. Benk, Oleg Kritsun, Tom Wallow, Deniz Civay, and Obert Wood. "Application of phase shift focus monitor in EUVL process control". In: *Proc. SPIE 8679, Extreme Ultraviolet (EUV) Lithography IV*. 2013. DOI: 10.1117/12.2011342. URL: http://dx.doi.org/10.1117/12.2011342.

Date: May 13, 2014.

[8] Kenneth A Goldberg, Iacopo Mochi, Markus P Benk, Arnaud P Allezy, Nathan S Smith, Carl W Cork, William Cork, James Macdougall, Weilun L Chao, Erik H Anderson, et al. "Creating an EUV Mask Microscope for Lithography Generations Reaching 8 nm". In: *Precision Engineering and Mechatronics Supporting the Semiconductor Industry* (2012), pp. 4–7.

[9] Tae-Geun Kim, Hwan-Seok Seo, In-Yong Kang, Chang Young Jeong, Sungmin Huh, Jihoon Na, Seong-Sue Kim, Chan-Uk Jeon, Iacopo Mochi, and Kenneth A. Goldberg. "Printability study of pattern defects in the EUV mask as a function of hp nodes". In: *Proc. SPIE 8322, Extreme Ultraviolet (EUV) Lithography III.* 2012. DOI: 10.1117/12.916052. URL: http://dx.doi.org/10.1117/12.916052.

[10] Hyuk Joo Kwon, Jenah Harris-Jones, Aaron Cordes, Masaki Satake, Ying Li, Iacopo Mochi, and Kenneth A. Goldberg. "EUV mask multilayer defects and their printability under different multilayer deposition conditions". In: *Proc. SPIE 8322, Extreme Ultraviolet (EUV) Lithography III.* 2012. DOI: 10.1117/12.916374. URL: http://dx.doi.org/10.1117/12.916374.

[11] Pei-Yang Yan, Iacopo Mochi, and Ken Goldberg. "EUV actinic imaging tool aerial image evaluation of EUVL embedded phase shift mask performance". In: *Proc. SPIE 8322, Extreme Ultraviolet (EUV) Lithography III.* 2012. DOI: 10.1117/12.919710. URL: http://dx.doi.org/10.1117/12.919710.

[12] Simi A. George, Patrick P. Naulleau, Eric M. Gullikson, Iacopo Mochi, Farhad Salmassi, Kenneth A. Goldberg, and Erik H. Anderson. "Replicated mask surface roughness effects on EUV lithographic patterning and line edge roughness". In: *Proc. SPIE 7969, Extreme Ultraviolet (EUV) Lithography II.* 2011. DOI: 10.1117/12.881524. URL: http://dx.doi.org/10.1117/12.881524.

[13] Kenneth A. Goldberg and Iacopo Mochi. "Actinic characterization of extreme ultraviolet bump-type phase defects". In: *Journal of Vacuum Science & Technology B* 29.6, 06F502 (2011). DOI: http://dx.doi.org/10.1116/1.3653257. URL: http://scitation.aip.org/content/avs/journal/jvstb/29/6/10.1116/1.3653257.

[14] Kenneth A. Goldberg, Iacopo Mochi, Senajith B. Rekawa, Nathan S. Smith, James B. Macdougall, and Patrick P. Naulleau. "An EUV Fresnel zoneplate mask-imaging microscope for lithography generations reaching 8 nm". In: *Proc. SPIE 7969, Extreme Ultraviolet (EUV) Lithography II.* 2011. DOI: 10.1117/12.881651. URL: http://dx.doi.org/10.1117/12.881651.

[15] Sungmin Huh, In-Yong Kang, Sang-Hyun Kim, Hwan-seok Seo, Dongwan Kim, Jooon Park, Seong-Sue Kim, Han-Ku Cho, Kenneth Goldberg, Iacopo Mochi, Tsutomu Shoki, and Gregg Inderhees. "Printability and inspectability of defects on the EUV mask for sub-32nm half pitch HVM application". In: *Proc. SPIE 7969, Extreme Ultraviolet (EUV) Lithography II.* 2011. DOI: 10.1117/12.879384. URL: http://dx.doi.org/10.1117/12.879384.

[16] Hyuk Joo Kwon, Jenah Harris-Jones, Ranganath Teki, Aaron Cordes, Toshio Nakajima, Iacopo Mochi, Kenneth A. Goldberg, Yuya Yamaguchi, and Hiroo Kinoshita. "Printability of native blank defects and programmed defects and their stack structures". In: *Proc. SPIE 8166, Photomask Technology 2011.* Vol. 8166. 2011. DOI: 10.1117/12.897165. URL: http://dx.doi.org/10.1117/12.897165.

[17] Iacopo Mochi, Kenneth A. Goldberg, Ryan Xie, Pei-Yang Yan, and Kenji Yamazoe. "Quantitative evaluation of mask phase defects from through-focus EUV aerial images". In: *Proc. SPIE 7969, Extreme Ultraviolet (EUV) Lithography II*. 2011. DOI: 10.1117/12.881652. URL: http://dx.doi.org/10.1117/12.881652.

[18] Patrick P. Naulleau, Kenneth A. Goldberg, Eric Gullikson, Iacopo Mochi, Brittany McClinton, and Abbas Rastegar. "Accelerating EUV learning with synchrotron light: mask roughness challenges ahead". In: *Proc. SPIE 8166, Photomask Technology 2011*. 2011. DOI: 10.1117/12.900488. URL: http://dx.doi.org/10.1117/12.900488.

[19] Patrick P. Naulleau, Iacopo Mochi, and Kenneth A. Goldberg. "Optical modeling of Fresnel zoneplate microscopes". In: *Appl. Opt.* 50.20 (July 2011), pp. 3678–3684. DOI: 10.1364/AO.50.003678. URL: http://ao.osa.org/abstract.cfm?URI=ao-50-20-3678.

[20] Patrick Naulleau, Christopher N. Anderson, Lorie-Mae Baclea-an, Paul Denham, Simi George, Kenneth A. Goldberg, Gideon Jones, Brittany McClinton, Ryan Miyakawa, Iacopo Mochi, Warren Montgomery, Seno Rekawa, and Tom Wallow. "Using synchrotron light to accelerate EUV resist and mask materials learning". In: *Proc. SPIE 7985, 27th European Mask and Lithography Conference*. 2011. DOI: 10.1117/12.885420. URL: http://dx.doi.org/10.1117/12.885420.

[21] Patrick Naulleau, Brittany McClinton, Kenneth A. Goldberg, Iacopo Mochi, and Abbas Rastegar. "Mask roughness challenges in extreme ultraviolet mask development". In: *Journal of Vacuum Science & Technology B* 29.6, 06F501 (2011). DOI: http://dx.doi.org/10.1116/1.3632989. URL: http://scitation.aip.org/content/avs/journal/jvstb/29/6/10.1116/1.3632989.

[22] A. J. R. van den Boogaard, E. Louis, K. A. Goldberg, I. Mochi, and F. Bijkerk. "EUV-multilayers on grating-like topographies". In: *Proc. SPIE 7636, Extreme Ultraviolet (EUV) Lithography*. 2010. DOI: 10.1117/12.846564. URL: http://dx.doi.org/10.1117/12.846564.

[23] Fernando Brizuela, Sergio Carbajo, Anne Sakdinawat, David Alessi, Dale H. Martz, Yong Wang, Bradley Luther, Kenneth A. Goldberg, Iacopo Mochi, David T. Attwood, Bruno La Fontaine, Jorge J. Rocca, and Carmen S. Menoni. "Extreme ultraviolet laser-based table-top aerial image metrology of lithographic masks". In: *Opt. Express* 18.14 (July 2010), pp. 14467–14473. DOI: 10.1364/OE.18.014467. URL: http://www.opticsexpress.org/abstract.cfm?URI=oe-18-14-14467.

[24] Yu-Jen Fan, Leonid Yankulin, Alin Antohe, Petros Thomas, Chimaobi Mbanaso, Rashi Garg, Yunfei Wang, Andrea Wuest, Frank Goodwin, Sungmin Huh, Patrick Naulleau, Kenneth Goldberg, Iacopo Mochi, and Gregory Denbeaux. "Effect of carbon contamination on the printing performance of extreme ultraviolet masks". In: *Journal of Vacuum Science & Technology B* 28.2 (2010), pp. 321–328. DOI: http://dx.doi.org/10.1116/1.3333434. URL: http://scitation.aip.org/content/avs/journal/jvstb/28/2/10.1116/1.3333434.

[25] Yu-Jen Fan, Leonid Yankulin, Petros Thomas, Chimaobi Mbanaso, Alin Antohe, Rashi Garg, Yunfei Wang, Thomas Murray, Andrea Wuest, Frank Goodwin, Sungmin Huh, Aaron Cordes, Patrick Naulleau, Kenneth Goldberg, Iacopo Mochi, Eric Gullikson, and Gregory Denbeaux. "Carbon contamination topography analysis of

EUV masks". In: *Proc. SPIE 7636, Extreme Ultraviolet (EUV) Lithography.* 2010. DOI: 10.1117/12.846996. URL: http://dx.doi.org/10.1117/12.846996.

[26] Simi A. George, Patrick P. Naulleau, Iacopo Mochi, Farhad Salmassi, Eric M. Gullikson, Kenneth A. Goldberg, and Erik H. Anderson. "Extreme ultraviolet mask substrate surface roughness effects on lithographic patterning". In: *Journal of Vacuum Science & Technology B* 28.6 (2010), C6E23–C6E30. DOI: http://dx.doi.org/10.1116/1.3502436. URL: http://scitation.aip.org/content/avs/journal/jvstb/28/6/10.1116/1.3502436.

[27] K. A. Goldberg and I. Mochi. "Wavelength-specific reflections: A decade of extreme ultraviolet actinic mask inspection research". In: *Journal of Vacuum Science & Technology B* 28.6 (2010), C6E1–C6E10. DOI: http://dx.doi.org/10.1116/1.3498757. URL: http://scitation.aip.org/content/avs/journal/jvstb/28/6/10.1116/1.3498757.

[28] Sungmin Huh, Abbas Rastegar, Stefan Wurm, Kenneth Goldberg, Iacopo Mochi, Toshio Nakajima, Masahiro Kishimoto, and Mitsuhiko Komakine. "Study of real defects on EUV blanks and a strategy for EUV mask inspection". In: *Proc. SPIE 7545, 26th European Mask and Lithography Conference.* 2010. DOI: 10.1117/12.863559. URL: http://dx.doi.org/10.1117/12.863559.

[29] Sungmin Huh, Liping Ren, David Chan, Stefan Wurm, Kenneth Goldberg, Iacopo Mochi, Toshio Nakajima, Masahiro Kishimoto, Byungsup Ahn, Inyong Kang, Joo-on Park, Kyoungyong Cho, Sang-in Han, and Thomas Laursen. "A study of defects on EUV masks using blank inspection, patterned mask inspection, and wafer inspection". In: *Proc. SPIE 7636, Extreme Ultraviolet (EUV) Lithography.* 2010. DOI: 10.1117/12.846922. URL: http://dx.doi.org/10.1117/12.846922.

[30] In-Yong Kang, Hwan-Seok Seo, Byung-Sup Ahn, Dong-Gun Lee, Dongwan Kim, Sungmin Huh, Cha-Won Koh, Brian Cha, Seoung-Sue Kim, Han-Ku Cho, Iacopo Mochi, and Kenneth Goldberg. "Printability and inspectability of programmed pit defects on the masks in EUV lithography". In: *Proc. SPIE 7636, Extreme Ultraviolet (EUV) Lithography.* 2010. DOI: 10.1117/12.847956. URL: http://dx.doi.org/10.1117/12.847956.

[31] I. Mochi, K. A. Goldberg, B. La Fontaine, A. Tchikoulaeva, and C. Holfeld. "Actinic imaging of native and programmed defects on a full-field mask". In: *Proc. SPIE 7636, Extreme Ultraviolet (EUV) Lithography.* 2010. DOI: 10.1117/12.846670. URL: http://dx.doi.org/10.1117/12.846670.

[32] Iacopo Mochi, Kenneth A Goldberg, and Sungmin Huh. "Actinic imaging and evaluation of phase structures on extreme ultraviolet lithography masks". In: *Journal of Vacuum Science & Technology B* 28.6 (2010), C6E11–C6E16. DOI: http://dx.doi.org/10.1116/1.3498756. URL: http://scitation.aip.org/content/avs/journal/jvstb/28/6/10.1116/1.3498756.

[33] Abbas Rastegar, Sean Eichenlaub, Arun John Kadaksham, Byunghoon Lee, Matt House, Sungmin Huh, Brian Cha, Henry Yun, Iacopo Mochi, and Kenneth Goldberg. "Particle removal challenges of EUV patterned masks for the sub-22nm HP node". In: *Proc. SPIE 7636, Extreme Ultraviolet (EUV) Lithography.* 2010. DOI: 10.1117/12.847056. URL: http://dx.doi.org/10.1117/12.847056.

[34] Daniel T. Wintz, Kenneth A. Goldberg, Iacopo Mochi, and Sungmin Huh. "Photon flux requirements for EUV reticle imaging microscopy in the 22- and 16nm nodes". In: *Proc. SPIE 7636, Extreme Ultraviolet (EUV) Lithography*. 2010. DOI: 10.1117/12.846528. URL: http://dx.doi.org/10.1117/12.846528.

[35] Daniel T. Wintz, Sungmin Huh, Kenneth A. Goldberg, and Iacopo Mochi. "Photon flux requirements for extreme ultraviolet reticle imaging in the 22- and 16-nm nodes". In: *Journal of Micro/Nanolithography, MEMS, and MOEMS* 9.4, 041205-041205-8 (2010). DOI: 10.1117/1.3491512. URL: http://dx.doi.org/10.1117/1.3491512.

[36] Chris H. Clifford, Tina T. Chan, Andrew R. Neureuther, Kenneth A. Goldberg, Iacopo Mochi, and Ted Liang. "Investigation of buried EUV mask defect printability using actinic inspection and fast simulation". In: *Proc. SPIE 7488, Photomask Technology 2009*. 2009. DOI: 10.1117/12.829716. URL: http://dx.doi.org/10.1117/12.829716.

[37] Chris H. Clifford, Sandy Wiraatmadja, Tina T. Chan, Andrew R. Neureuther, Kenneth A. Goldberg, Iacopo Mochi, and Ted Liang. "Comparison of fast three-dimensional simulation and actinic inspection for extreme ultraviolet masks with buried defects and absorber features". In: *Journal of Vacuum Science & Technology B* 27.6 (2009), pp. 2888–2893. DOI: http://dx.doi.org/10.1116/1.3244624. URL: http://scitation.aip.org/content/avs/journal/jvstb/27/6/10.1116/1.3244624.

[38] Chris H Clifford, Sandy Wiraatmadja, Tina T Chan, Andrew R Neureuther, Kenneth A Goldberg, Iacopo Mochi, and Ted Liang. "Extreme Ultraviolet Lithography-Comparison of fast three-dimensional simulation and actinic inspection for extreme ultraviolet masks with buried defects and absorber features". In: *Journal of vacuum science & technology. B, Microelectronics and nanometer structures* 27.6 (2009), pp. 2888–2893. DOI: http://dx.doi.org/10.1116/1.3244624. URL: http://scitation.aip.org/content/avs/journal/jvstb/27/6/10.1116/1.3244624.

[39] Yu-Jen Fan, Leonid Yankulin, Alin Antohe, Rashi Garg, Petros Thomas, Chimaobi Mbanaso, Andrea Wuest, Frank Goodwin, Sungmin Huh, Patrick Naulleau, Kenneth Goldberg, Iacopo Mochi, and Gregory Denbeaux. "Carbon contamination of extreme ultraviolet (EUV) masks and its effect on imaging". In: *Proc. SPIE 7271, Alternative Lithographic Technologies*. 2009. DOI: 10.1117/12.814196. URL: http://dx.doi.org/10.1117/12.814196.

[40] K. A. Goldberg, I. Mochi, P. Naulleau, T. Liang, P.-Y. Yan, and S. Huh. "EUV pattern defect detection sensitivity based on aerial image linewidth measurements". In: *Journal of Vacuum Science & Technology B* 27.6 (2009), pp. 2916–2921. DOI: http://dx.doi.org/10.1116/1.3264676. URL: http://scitation.aip.org/content/avs/journal/jvstb/27/6/10.1116/1.3264676.

[41] Kenneth A. Goldberg, Iacopo Mochi, and Sungmin Huh. "Collecting EUV mask images through focus by wavelength tuning". In: *Proc. SPIE 7271, Alternative Lithographic Technologies*. 2009. DOI: 10.1117/12.824433. URL: http://dx.doi.org/10.1117/12.824433.

[42] Sungmin Huh, Patrick Kearney, Stefan Wurm, Frank Goodwin, Kenneth Goldberg, Iacopo Mochi, and Eric Gullikson. "Mask defect verification using actinic

inspection and defect mitigation technology". In: *Proc. SPIE 7271, Alternative Lithographic Technologies*. 2009. DOI: 10.1117/12.814249. URL: http://dx.doi.org/10.1117/12.814249.

[43] Sungmin Huh, Patrick Kearney, Stefan Wurm, Frank Goodwin, Hakseung Han, Kenneth Goldberg, Iacopo Mochi, and Eric Gullikson. "EUV actinic defect inspection and defect printability at the sub-32-nm half-pitch". In: *Proc. SPIE 7470, 25th European Mask and Lithography Conference*. 2009. DOI: 10.1117/12.835196. URL: http://dx.doi.org/10.1117/12.835196.

[44] Hiroyuki Mizuno, Gregory McIntyre, Chiew-seng Koay, Martin Burkhardt, Long He, John Hartley, Corbet Johnson, Sudharshanan Raghunathan, Kenneth Goldberg, Iacopo Mochi, Bruno La Fontaine, and Obert Wood. "Thorough characterization of an EUV mask". In: *Proc. SPIE 7379, Photomask and Next-Generation Lithography Mask Technology XVI*. 2009. DOI: 10.1117/12.824260. URL: http://dx.doi.org/10.1117/12.824260.

[45] Iacopo Mochi, Kenneth A. Goldberg, Patrick Naulleau, and Sungmin Huh. "Improving the performance of the actinic inspection tool with an optimized alignment procedure". In: *Proc. SPIE 7271, Alternative Lithographic Technologies*. 2009, p. 727123. DOI: 10.1117/12.814261. URL: http://dx.doi.org/10.1117/12.814261.

[46] Sheng Yuan, Kenneth Goldberg, Valeriy V. Yashchuk, Richard Celestre, Tony Warwick, Wayne R. McKinney, Gregory Morrison, Senajith B. Rekawa, Iacopo Mochi, and Howard A. Padmore. "At-Wavelength and Optical Metrology of Bendable X-Ray Optics for Nanofocusing at the ALS". In: *Frontiers in Optics 2009/Laser Science XXV/Fall 2009 OSA Optics & Photonics Technical Digest*. Optical Society of America, 2009. DOI: 10.1364/FIO.2009.FThT2. URL: http://www.opticsinfobase.org/abstract.cfm?URI=FiO-2009-FThT2.

[47] K. A. Goldberg, P. Naulleau, I. Mochi, E. H. Anderson, S. B. Rekawa, C. D. Kemp, R. F. Gunion, H.-S. Han, and S. Huh. "Actinic extreme ultraviolet mask inspection beyond 0.25numericalaperture". In: *Journal of Vacuum Science & Technology B* 26.6 (2008), pp. 2220–2224. DOI: http://dx.doi.org/10.1116/1.3002490. URL: http://scitation.aip.org/content/avs/journal/jvstb/26/6/10.1116/1.3002490.

[48] Kenneth A. Goldberg, Iacopo Mochi, Patrick P. Naulleau, Hakseung Han, and Sungmin Huh. "Benchmarking EUV mask inspection beyond 0.25 NA". In: *Proc. SPIE 7122, Photomask Technology 2008*. 2008. DOI: 10.1117/12.801529. URL: http://dx.doi.org/10.1117/12.801529.