Impact of base and PAG loading on intrinsic resolution in EUV resists

Christopher N. Anderson,[1,2] Patrick P. Naulleau,[1,3] Dimitra Niakoula,[1]
Elsayed Hassanein,[3] Robert Brainard,[3] Gregg Gallatin,[4] and Kim Dean[5]

[1] *Center for X-Ray Optics, Lawrence Berkeley National Laboratory, Berkeley, CA 94720*
[2] *Applied Science & Technology Graduate Group, University of California, Berkeley, CA 94720*
[3] *College of Nanoscale Science and Engineering, University at Albany, NY 12203*
[4] *Applied Math Solutions, LLC*
[5] *SEMATECH, Austin, TX 78741*

Extreme ultraviolet (EUV) lithography continues to be the leading candidate for high-volume chip production beyond the 32-nm technology node and has now entered the commercialization phase.[1,2] The ability of EUV resists to simultaneously achieve the resolution, sensitivity and line-edge-roughness (LER) requirements for commercialization, however, remains one of the biggest challenges facing EUV[3] Of these benchmarks, resolution is arguably the most important; it is also the most difficult to objectively quantify. To address the issue of intrinsic resolution quantification, a variety of methods have been developed[4,5,6,7]. Here we use a contact-hole metric[7] to investigate intrinsic resolution as a function of resists base and photo-acid-generator (PAG) concentration.

It has been speculated that the resolution of chemically amplified resists is determined largely by the acid diffusion during the post-exposure bake[4, 1]. It is generally believed that increased base loading leads to improved resolution by reducing the amount of photo-generated acids that contribute to the chemical amplification process, thereby reducing the acid diffusion length during the post-exposure bake. Results from the

---

[1] H. Meiling, et. al, “First performance results of the ASML alpha demo tool,” Proc. SPIE 6151, 615108 (2006).
[2] M. Miura, K. Murakami, K. Suzuki, Y. Kohama, Y. Ohkubo, T. Asami, “Nikon EUVL development progress summary,” Proc. SPIE 6151, 615105 (2006).
[3] B. Wu and A. Kumar, "Extreme ultraviolet lithography: A review," J. Vac. Sci. Technol. B 25(6), Nov/Dec 2007.
[4] G. M. Schmid, M. D. Stewart, C. Wang, B. D. Vogt, M. Vivek, E. K. Lin, C G Willson, ``Resolution limitations in chemically amplified photoresist systems," Proc. of SPIE 5376, 333-342, (2004).
[5] G. F. Lorusso, P. Leunissen, M. Ercken, C Delvaux, F.V. Roey, N. Vandenbroeck, ``Spectral analysis of line width roughness and its applications to immersion lithography," J. Microlith., Microfab., Microsyst. 5(2) 033003 (2006).
[6] J. Hoffnagle, W. D. Hinsberg, F. A. Houle, and M. I. Sanchez, ``Characterization of photoresist spatial resolution by interferometric lithography", Proc. of SPIE 5038, 464-472 (2003).
[7] C. Anderson and P. Naulleau, “Sensitivity study of two high-throughput resolution metrics for photoresists,” Appl. Opt. Vol 47, No. 1 (2008).
[8] Y. Tanaka, Y. Kikuchi, D. Goo, and I. Nishiyama, Proc. SPIE 6517, 65172L（2007).

contact printing metric (Figure 1) show that for several independent resist formulations, resolution is improved by increasing the relative amount of base incorporated into the resist. This effect, however, is shown to saturate at high base loading in some cases. The contact metric has also been used to study the effect of PAG concentration. The results show no statistically significant dependence of measured intrinsic resolution on PAG concentration.

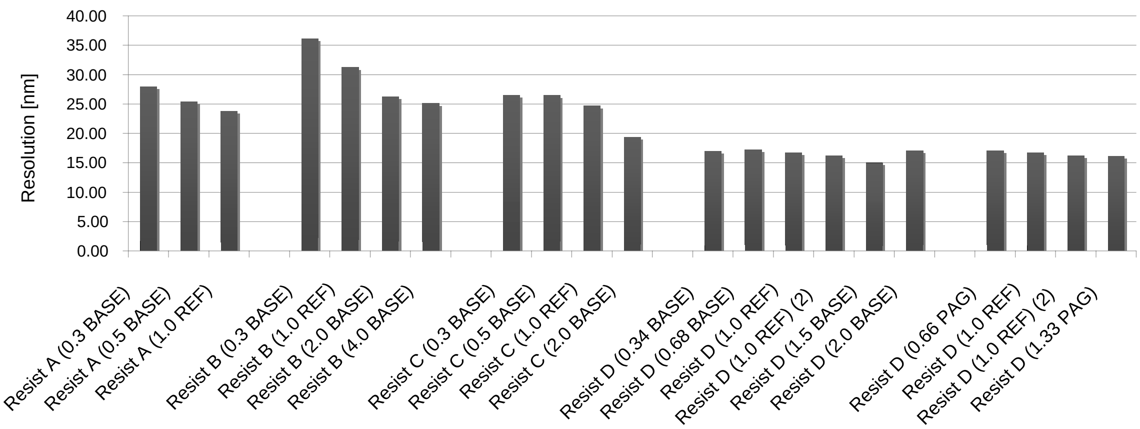

Figure 1: Resist resolution using the high-throughput contact printing metric[7]. Four resist platforms are shown (A, B, C, & D), each with several levels of base loading. Indicated baseload levels (i.e., 0.3) are relative to the reference formula (1.0) for each platform. For platform D we also show resolution for different levels of PAG concentration. Error bars on extracted resolution are modeled at 1.23 nm-rms[7].