EUV Tip-to-Tip Variation Mitigation for Beyond 7nm BEOL Layers and Design Rule Analysis

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EUV patterning, especially tip-to-tip (T2T) features, has been known to be susceptible to random variations due to stochastic effects[1]. For back end of line (BEOL) layers, T2T control is particularly important, because connections between metal layers are almost always located at line ends. Large T2T variability takes up the increasingly stringent overlay budget and ultimately leads to defects. Although many factors give rise to stochastic variations in EUV lithography, sharper aerial image almost always leads to better CD uniformity on wafer. A simple model that correlates the stochastic edge placement error in EUV patterning and the image log-slope (ILS) has been identified and experimentally verified to work well with arbitrary shapes[2].

To print diversified patterns in BEOL layers, such as those in random logic, using single exposure, a delicate choice of the source has to be made. We run source mask optimization (SMO) with ILS incorporated in the cost function[3] for a variety of T2T features, including orthogonal and staggered bars with different lengths, and discover that the ILS cannot be increased simultaneously for all features, as shown in Table 1. The root cause is found to be the competition over "ideal" locations in the source pupil by different features, which in turn can be traced back to diffraction optics and coherent image formation theory. It is expected that improved resists would allow better CD control at lower ILS. We will discuss the optimal pitch and T2T combination with different ILS thresholds, hence provide an estimation of how good the resist should be in order to meet the requirements of advanced technology nodes. Our work will be able to aid the generation of design rules specific to T2T printability so that hot spots can be avoided before time-consuming optical rule check and expensive wafer validation. Another promising solution is to open up the degrees of freedom in designs by "design intent" optimization[4].

Reference

[1] De Bisschop, P., Van de Kerkhove, J., Mailfert, J., Vaglio Pret, A., and Biafore, J. *Proc. SPIE* **9048**, 904809 (2014)
[2] Hansen, S. US Patent application 61/938,554
[3] Hsu, S., Howell, R., Jia, J., Liu, H.-Y., Gronlund, K., Hansen, S., and Zimmermann, J. *Proc. SPIE* **9422**, 94221I (2015)
[4] Crouse, M., Liebmann, L., Chen, Y., Plachecki, V., Saulnier, N., Dunn, D., Guillorn, M., Hsu, S., Gronlund, K., and Goodwin, F. *to be published*

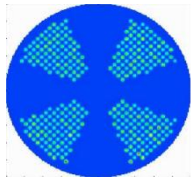
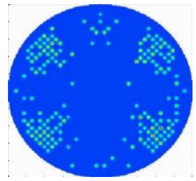
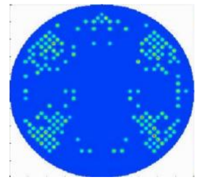
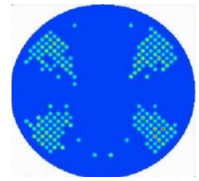
Simulation Type	Mask Optimization	SMO (Weight$_{T2T}$=50)	SMO (Weight$_{T2T}$=100)	SMO (Weight$_{T2T}$=1000)
Source Shape				
T2T Feature 1	71.4	83.4	82.3	85.8
T2T Feature 2	71.0	76.4	75.8	75.4
T2T Feature 3	84.8	87.6	85.8	92.8
T2T Feature 4	81.8	81.5	79.9	79.1

Table 1 ILS values at line ends for four distinct T2T features when the source is the standard Quasar 45 and optimized using SMO. It can be seen that the ILS for T2T feature 4 degrades as more weight is assigned to tagged T2T edges. Green and yellow numbers mean improvement and deterioration compared with the baseline case (mask optimization), respectively.