Lithography-Patterning-Fidelity-Aware Electron-Optical System Design Optimization

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Low-energy electron beam lithography is a promising patterning solution for the 22-nm half-pitch node and beyond due to its high resolution, low substrate damage, and increased resist sensitivities. To ensure a successful electron-optical system (EOS) design, many factors such as focusing properties (FP) and patterning fidelity (PF) have to be considered. A traditional EOS optimization flow is schematically shown in the red part of Figure 1. Focusing properties are typical performance indices specified when optimizing the EOS design parameters. In each design iteration, the EOS simulation results are compared with the performance indices. The differences are reduced by adjusting the parameters until convergence. However, the performance indices related to focusing properties have no direct relationship to lithography patterning fidelity which is judged by the quality of developed resist patterns. A new EOS design methodology which directly incorporates lithography patterning fidelity metrics into the optimization flow is schematically shown in the Figure 1. The initial values of EOS design parameters and geometry constraints are first optimized using the traditional design flow to obtain acceptable focusing properties. In order to ensure lithography patterning fidelity, writing patterns are selected and writing parameters are optimized. Then, constraints and cost functions related to patterning fidelity are selected to optimize the EOS parameters to obtain acceptable patterning fidelity. In each design iteration, the lithography patterning results are compared against corresponding drawn layouts. Their differences are reduced by adjusting the parameters until all constraints are met and patterning fidelity cost functions are converged. One EOS structure design includes a single-gate source, an aperture, and a focus lens as shown in Figure 2.[1] Initial values of EOS design parameters and geometry constraints are selected.[1-3] This is a 5-keV electron beam lithography system and a drawn layout for a 22 nm isolated line pattern is used for verifying the ITRS lithography patterning fidelity specifications. After optimizing the design parameters for focusing properties, the developed resist pattern is shown in the red contour of Figure 3. Its corresponding value of critical dimension (CD) is 26.0 nm. The developed resist pattern after applying the proposed patterning-fidelity-aware method is shown in the blue contour of Figure 3. Its corresponding value of CD is 22.68 nm. It is clear that the patterning fidelity is significantly improved as shown in Table I.

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[1] M. G. R. Thomson, and T. H. P. Chang: J. Vac. Sci. Technol. B **13**, 1995, p. 2445.

[2] E. Kratschmer, H. S. Kim, M. G. R. Thomson, K. Y. Lee, S. A. Rishton, M. L. Yu, S. Zolgharnain, B. W. Hussey, and T. H. P. Chang: J. Vac. Sci. Technol. B **14**, 1996, p. 3792.

[3] S. Y. Chen, S. C. Chen, H. H. Chen, K. Y. Tsai, and H. H. Pan: Jpn. J. Appl. Phys. 49, 2010, p. 06GE05-1.

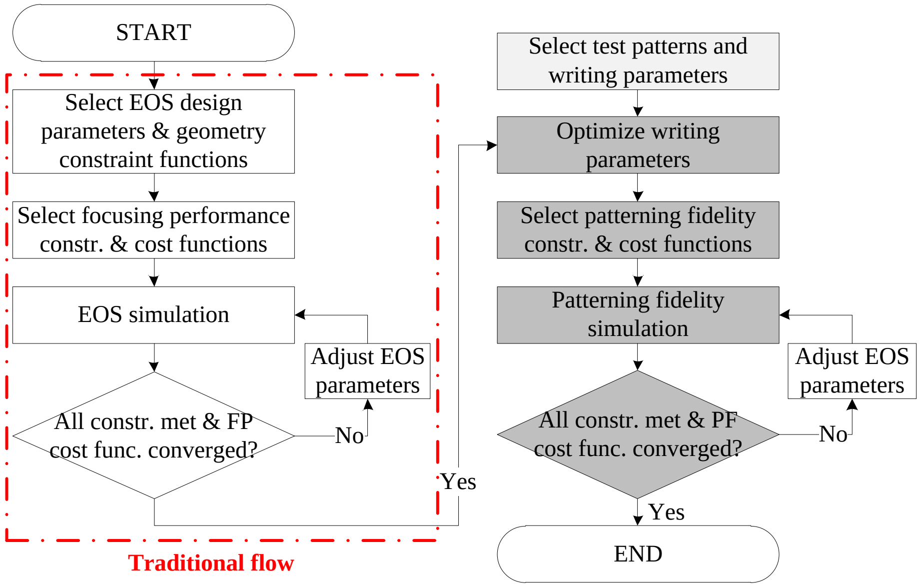

Figure 1: EOS design optimization flows.

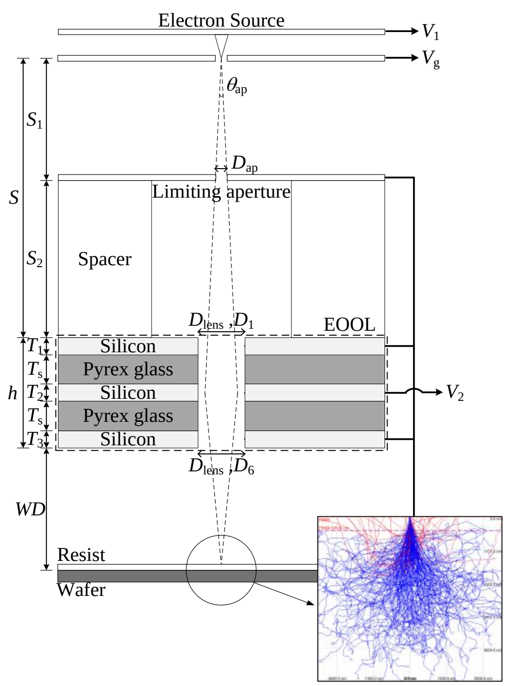

Figure 2: A single-gate EOS and design parameters.

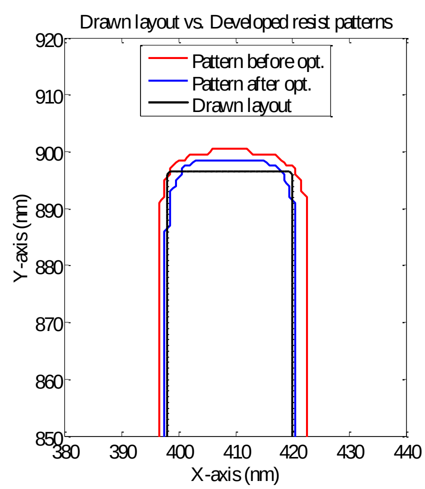

Figure 3: Comparison of developed resist patterns.

Table I: Comparison of critical dimensions before and after applying the proposed patterning-fidelity-aware optimization.

Parameter	CD value (nm)	Error percentage (%)
Drawn layout	22	×
Before opt.	26	18.18
After opt.	22.68	3.09