Study of Sub-Resolution Assist Feature Placement on Focus Robustness Using Computationally Efficient Defocus Information

Jianliang Li, Qiliang Yan, Lawrence S. Melvin III
Synopsys Inc., 2025 NW Cornelius Pass Rd., Hillsboro OR 97124, USA
jlli@synopsys.com

Driven by the ever shrinking feature size in the chip design and the complexity of the heuristic Sub-Resolution Assist Feature (SRAF) placement rules more wafer data for calibration and more effort on the part of design engineers is necessary for each process node. The main purpose of placing SRAFs around the main feature is to improve focus robustness on the target edge of the main feature. Therefore, it is desirable to study the effect of SRAF placement on main feature in terms of focus sensitivity with a computationally rapid and accurate algorithm. In this paper, a methodology of calculating the defocus signal dependence on SRAF placement in an iso-line pattern is proposed.

Conventionally, computing the SRAF effect on through focus behavior is straight forward, but time-consuming and computationally expensive. One needs to calculate the intensity difference I_Δ at the evaluation point with the original pattern, and then redo the same I_Δ calculation for the pattern with assist features placed at a perturbated location. The change in I_Δ (labeled as δI_Δ) is recorded for this perturbation. Using this scheme to determine optimal SRAFs placement, many locations must be examined. To scan a curve of assist features placement on a pattern, hundreds of these data points mentioned above may be needed. However, by examining the difference of the Hopkins equation with and without AF placement, an innovative way of calculating the effect of assist features on the main feature can be found, as shown in eq. (1) in Fig. 1, in which, $M_{AF}(x,y;x_0,y_0)$ is the new mask transmission function with assist features included, and $\delta M(x-x_0 ,y-y_0)$ is the mask transmission function of the assist features placed at location of (x_0 ,y_0). Then, the AF placement effect on the through focus behavior of the main feature can be computed as shown in eq. (2) in Fig. 1. Without any iteration, this method generates accurate output of the signal change due to the SRAFs placed at any desired location.

The results calculated in conventional method, the new method and first-principle simulator are compared together. Further investigation on different main features indicates the optimal location for the SRAF placement to increase the depth of focus can be rapidly determined for any process configuration. The results are verified by using independent tools and measured before and after optical proximity correction (OPC). Consistency of the optimal assist features location is observed, and a qualitative explanation of the observations is presented.

Keywords: assist features, OPC, iso-line, process latitude, photolithography

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\begin{aligned}
I_{AF}(x,y;x_0,y_0) &= \sum_{i=1}^{\infty} \lambda_i \left| \iint M_{AF}(x_1,y_1;x_0,y_0) K_i(x-x_1,y-y_1) dx_1 dy_1 \right|^2 \\
&= \sum_{i=1}^{\infty} \lambda_i \left| \iint \left[M(x_1,y_1) + \delta M(x_1-x_0,y_1-y_0) \right] K_i(x-x_1,y-y_1) dx_1 dy_1 \right|^2 \\
&\cong \sum_{i=1}^{\infty} \lambda_i \left| \iint M(x_1,y_1) K_i(x-x_1,y-y_1) dx_1 dy_1 \right|^2 + \\
& \sum_{i=1}^{\infty} 2\lambda_i \iint M(x_1,y_1) K_i(x-x_1,y-y_1) dx_1 dy_1 \bullet \\
& \iint \delta M(x_1-x_0,y_1-y_0) K_i(x-x_1,y-y_1) dx_1 dy_1 \\
&= I(x,y) + \delta I(x-x_0,y-y_0),
\end{aligned} \quad . \quad (1)
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\begin{aligned}
\delta I_{\Delta} &= I_{\Delta}(AF) - I_{\Delta}(no\_AF) \\
&= \left[I_{BF}(AF) - I_{DF}(AF) \right] - \left[I_{BF}(no\_AF) - I_{DF}(no\_AF) \right]. \\
&= \delta I_{BF} - \delta I_{DF}
\end{aligned} \quad (2)
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Fig. 1. Equations for assist features placement calculation