

Fogging effect correction method in high-resolution electron beam lithography

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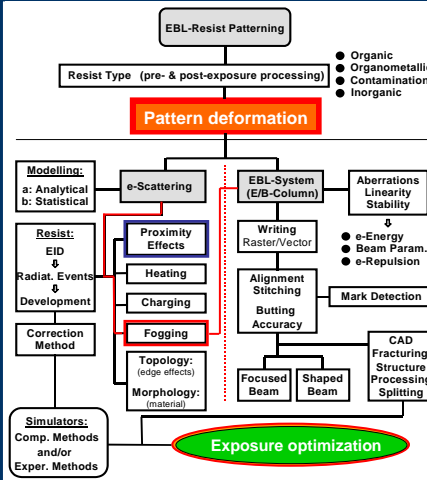
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Abstract:

We report on a fogging effect correction (FEC) method to be used in EBL. In the new version of **PROX-In** software tool was the possibility of correcting for *large-range pattern distortion effects* implemented in connection with the modified **PROXECCO** tool. This combination allows a complex exposure optimization by dose modulation of long-range fogging and/or loading effects with the standard PEC method using the same corrector. This approach is fast and effective, does not use any special additional technology steps and uses only standard high-resolution measuring techniques.



Process calibration - taking into account:

a) Process dependent effects:

I. Short-range effects:

- scattering of electrons (EID);
- resist development (pattern geometry);
- local heating effect;
- charging, topography, morphology, ...

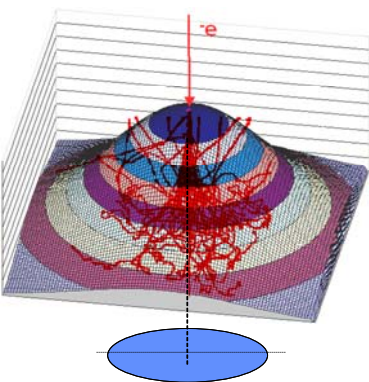
II. Long-range effects:

- re-scattering of electrons (Fogging);
- substrate process homogeneity;

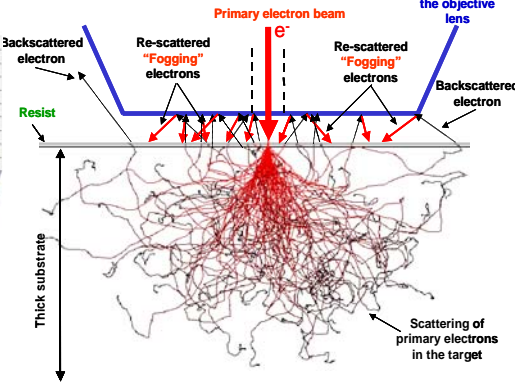
c) Tool dependent effects:

- e-beam characteristics (aerial image);

Proximity Effect: scattering of electrons



Fogging Effect: re-scattering of electrons



Point Exposure Intensity Distribution approximated by 2 Gauss functions (most commonly assumed form)

Short-range PSF_{PEC}:

$$f(r) = c_f G_f + c_b G_b$$

$$G_f(r) = \exp\left(-\frac{r^2}{\alpha^2}\right)$$

$$G_b(r) = \exp\left(-\frac{r^2}{\beta^2}\right)$$

$$I_f = \int_0^{2\pi\pi} \int_0^{2\pi\pi} c_f \exp\left(-\frac{r^2}{\alpha^2}\right) dr d\phi$$

$$I_b = \int_0^{2\pi\pi} \int_0^{2\pi\pi} c_b \exp\left(-\frac{r^2}{\beta^2}\right) dr d\phi$$

$$\eta = \frac{I_b}{I_f}$$

Log(Intensity)

Long-range PSF_{FEC}:

$$f_{FEC}(r) = c_f G_f$$

$$G_f(r) = \exp\left(-\frac{r^2}{\gamma_F^2}\right)$$

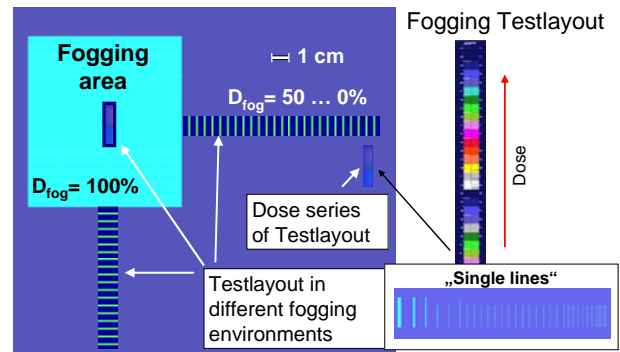
Log(Intensity)

Common PSF_{PEC+FEC}:

$$f_{FEC+PEC}(r) = c_f G_f + c_b G_b + c_f G_f$$

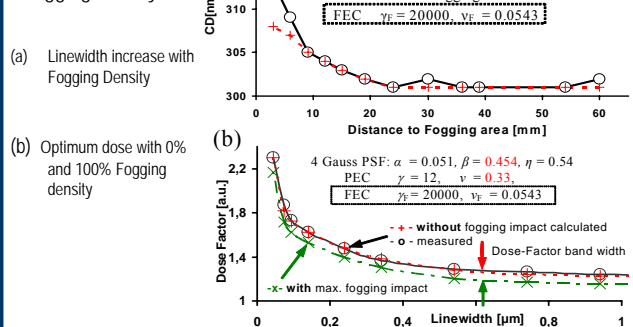
$$f_{PEC+FEC}(r) = c \left(\frac{1}{\alpha^2} \exp\left(-\frac{r^2}{\alpha^2}\right) + \frac{\eta}{\beta^2} \exp\left(-\frac{r^2}{\beta^2}\right) + \frac{\nu_F}{\gamma_F^2} \exp\left(-\frac{r^2}{\gamma_F^2}\right) \right)$$

Fogging Effect Correction



PSF_{FEC} Parameter Determination Based on

Measurement and Back-Simulation of Fogging Testlayout



Fogging Effect correction using PROXECCO with FEC extension of real APSM

400nm Isolated dark line on mask

GCDU (range) ≤ 6 nm
GCDU (3σ) ≤ 5.1 nm

Before Correction

After Correction

