Tools for Resist Heating Analysis and Compensation for Electron Beam Tools

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Abstract

Substrate heating due to electron beam irradiation is of major concern in high throughput electron beam lithography. As the device dimensions continue to shrink, this assumes an even greater importance as the specifications for CD control and image placement get tighter. Energy from the beam is deposited in the resist during pattern writing. A large fraction of the energy incident is not absorbed by the resist for any useful chemistry. This unused energy results in the heating up of the multi-layer stack of resist, chrome/absorber (mask writing) and substrate. The amount of temperature rise depends on a multitude of factors including beam current density, thermal properties of the substrate stack and also on the pattern being exposed. The rise in temperature affects the resist sensitivity. The dose to clear for an electron beam resist is a temperature dependent function[1]. Any change from the optimal dose resulting from temperature rise affects CD of the feature being printed. Figure 1 shows the change in relative CD as a function of relative dose for a simple Gaussian beam assuming the full width at half maximum (FWHM) as the resist threshold. The relative dose change in the case of substrate heating is a linear function of temperature change for electron beam resists.

Various compensation methods have been available through the years to reduce the substrate heating effects. They include multi-pass writing, reduced beam current density and subfield scheduling to name a few. This paper will touch upon the drawbacks of these techniques and present a novel yet simple method of substrate temperature control - pixel level dose modulation. The substrate temperature simulations are based on the multi-layer Green's function solution[2] to the heat equation. Pixel level dose modulation for proximity effect correction has been well studied and implemented in electron beam

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[1] .Babin, J. Vac. Sci. Technol. B 21(1), Jan/Feb 2003

[2] D.Chu et.al, Proceedings of SPIE -- Volume 4689, Metrology, Inspection, and Process Control for Microlithography XVI, July 2002, pp. 206-212

lithography for a long time. A composite dose correction strategy that would include temperature effects in addition to proximity effect would be simple enough to implement without major modifications to the system architecture. Simulations and experimental results for this method will be presented for a simple contact array type structure of different pitch and CD values (figure 2) to illustrate the pixel level dose correction.

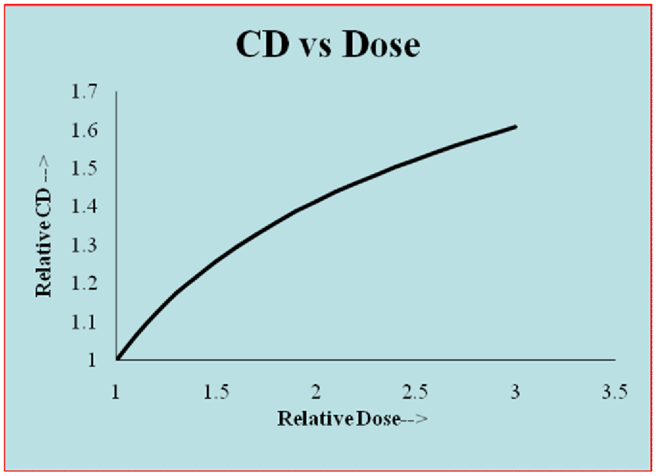

Figure 1: Change in relative CD with change in relative dose

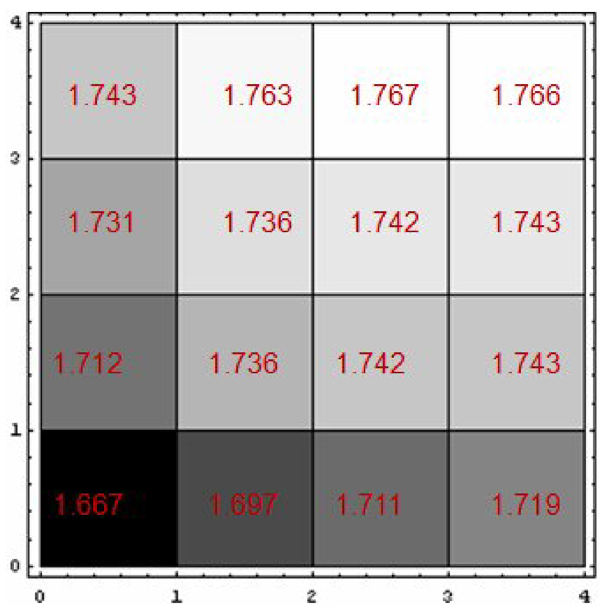

Figure 2: Illustration of relative CD calculation resulting from resist heating for 4x4 contact array