Continuous and Stochastic effects for 2D structures in EUV Lithography

A. Vaglio Pret, P. de Bisschop
Imec, Kapeldreef 75, B-3001 Leuven, Belgium
vaglio@imec.be

In extreme UV lithography, stochastic effects as Photon[1,2] and Acid Shot Noise (PSN, ASN)[3] influence the pattern fidelity of printed features. In figure 1, Line Width Roughness (LWR) of different resists with different Photo-Acid Generator (PAG) and Quencher concentrations are reported upon exposure dose. On the right graph, the same data are reported as function of the inverse of the square root of the dose, or PSN. The good linear fit demonstrates how the roughness is highly correlated with the number of photons absorbed to print the features into the resist[4]. In traditional optical lithography (ArF, KrF), where the discrete characteristic of light is negligible, the final printed layout can be fine-tuned via Optical Proximity Corrections (OPC)[5]. This technique consist of small modifications of the mask layout which locally improve the aerial image quality (figure 2a,b). OPC, obtained iteratively simulating the optimum mask layout to achieve the desired target at wafer level, are particularly effective for features smaller than the wavelength. These optical simulations, based on Fourier analysis, determine continuous contour plots of the aerial image (figure 2c-e); however, they do not take into account the discrete nature of light.
For extreme UV lithography this approach is not enough to capture random pattern failure at wafer level for sub-20nm features, and stochastic modeling is necessary for such energetic photons[6] (figure 2f,g).
In this paper, a combination of experimental and simulated results is used to discriminate pattern failures due to poor image quality, hence optically correctable via OPC, from random failures due to stochastic phenomena. It was found that slower materials (which requires higher exposure dose) or more performing lithographic tools (with higher numerical aperture) are not necessarily exhaustive solutions when singly implemented with 2D random structures, as graphically shown in figure 3a,b.
Once again, a compromise between reasonable exposure dose and more performing lithographic tools will be a must for logic applications (figure 3c), although "stochastic-effect aware OPC" may be beneficial to identify critical structures for both continuous and stochastic effects.

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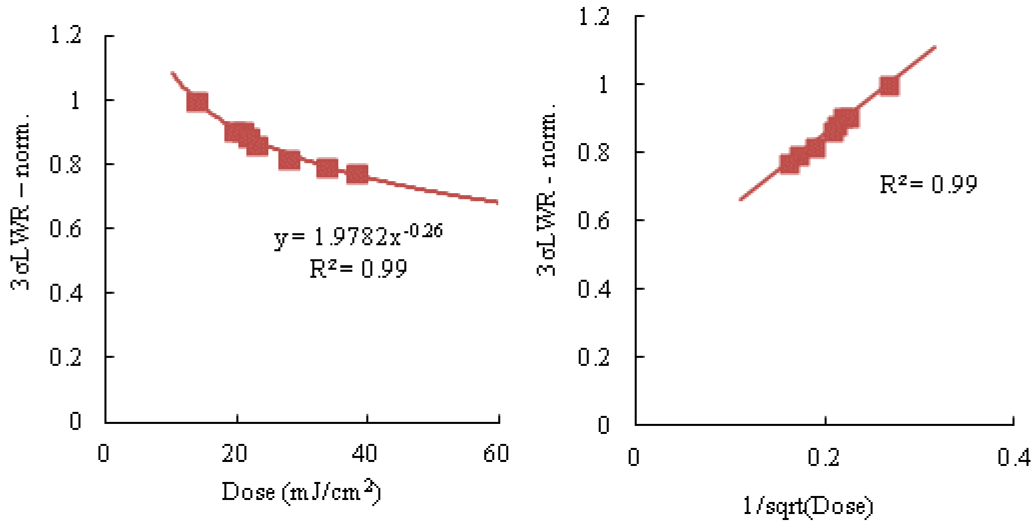

Figure 1: left) normalized LWR of resists with different PAG/Quencher concentrations upon exposure doses. Right) the same data set plotted upon PSN (1/√Dose).

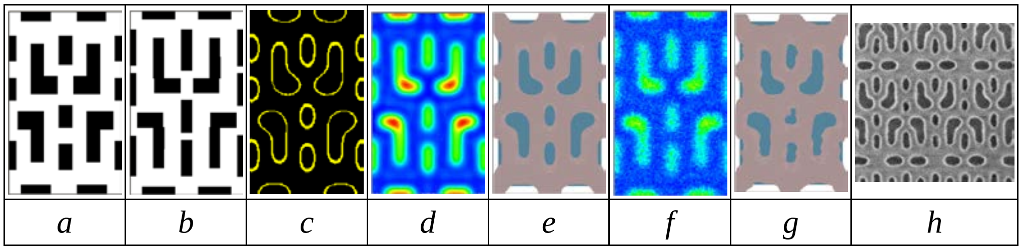

Figure 2: 14nm random logic mask layout before (a) and after (b) OPC. c,d,e) continuous simulations of aerial image contour plot, intensity distribution and resist response of layout b). f,g) stochastic simulations of layout b). h) layout b) at wafer level.

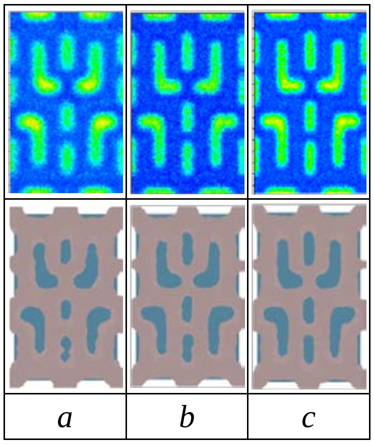

Figure 3: stochastic exposures of layout 2b) with 2x slower material (a) more performing lithographic tool (b) and the combination of both (c).