Feature proximity effects on the roughness and size variability of electron beam contact patterns

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One of the great challenges in nanolithography is to provide structures with low edge roughness and CD variability. In beam lithographies, these challenges are usually related to a) shot noise effects emanated from the relatively small number of involved incident particles (electrons or photons) and b) uncontrolled chemical inhomogeneities of resist composition (chemical noise).

In many applications (i.e. memory devices), the miniaturization of dimensions comes along with ultra-high pattern densities where the processing of neighboring features may affect each other and contribute to the degradation of their quality. However, a quantitative and systematic assessment of these feature proximity effects (FPE) is still lacking.

In this paper, we investigate the FPE in contact layers opened in PMMA resist by 100keV e-beam lithography. One way to isolate the impact of FPE on contact quality is to study the dependence of Contact Edge Roughness (CER) and CD variability on the exposure dose for fixed pitch, since at high doses, both shot and chemical noise effects are expected to diminish. Fig. 1 shows the results for the RMS value of CER (a) and the CD variation (b) versus dose along with representative SEM images in insets. Both metrics exhibit increasing trends with dose revealing the contribution of FPE on the deterioration of contact shape and uniformity (cf. similar results for EUVL in [1]). The footprint of FPE is more clearly shown in the frequency analysis of CER. Fig. 2 shows representative Power Spectra (PS) for low (black), intermediate (blue) and high (red) doses. The PS curves are almost identical at high and intermediate frequencies but differ at low ones where the high doses get higher values. The low frequencies correspond to deformations of the contact edge from the circular shape which can be directly linked to the preferential action of FPE along the directions of the contact lattice. Further results of the paper concern the FPE on the pattern transfer of contacts as well as modeling and simulation approaches based on previous works on line/space gratings [2] to pinpoint the critical factors in FPE.

[1] V.-K.M. Kuppuswamy et al., J. Micro/Nanolith. MEMS MOEMS **12**, 023003 (2013)
[2] G.P. Patsis et al., Microelectr. Eng. **87**, 1575 (2010)

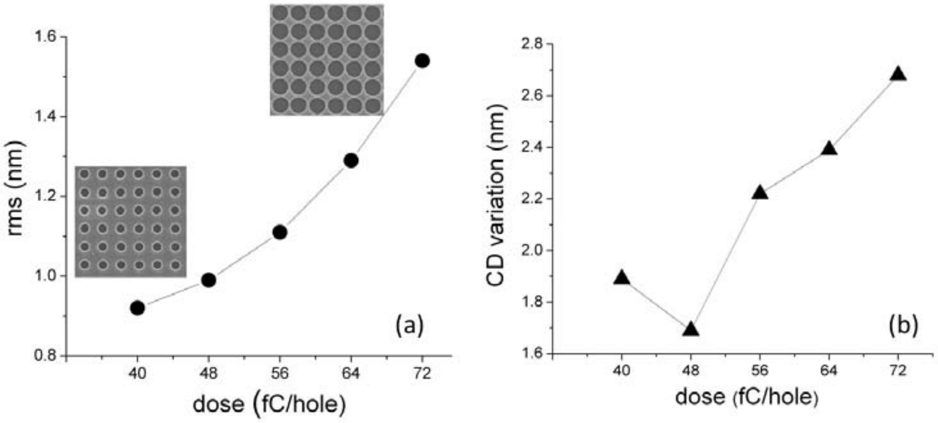

Figure 1: RMS value of Contact Edge Roughness (a) and CD variation (b) versus exposure dose for pitch=200nm. In (a) two top-down SEM images of contact layers at low (100μC/cm^2) and high (180μC/cm^2) are shown in insets. Notice the increasing trends in both diagrams which may be related to the increased proximity of contacts with dose.

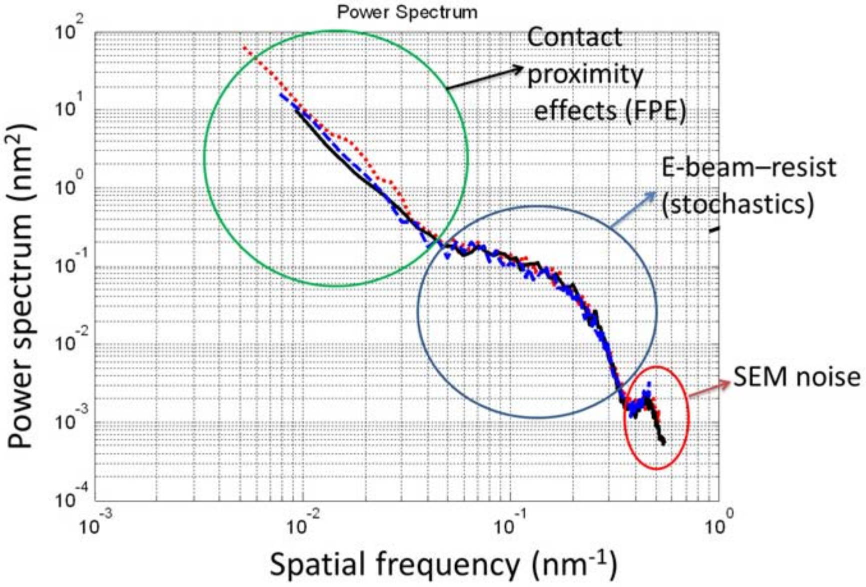

Figure 2: Power spectra of contact edges for low (full), intermediate (dashed) and high (dotted) doses. Notice the difference at low frequencies indicating the degradation effects of contact proximity along the directions of the pattern lattice.