Process Window Enhancement through Shape Proximity Effect Correction of an Electron Beam Lithography Process

Kashif M. Awan[a], Gerald Lopez[b], Lukas Chrowstoski[a,c] and Jeff F. Young[a,d]

a. Advanced Materials and Process Engineering Laboratory and the Stewart Blusson Quantum Matter Institute, University of British Columbia
b. Singh Center for Nanotechnology, University of Pennsylvania
c. Department of Electrical and Computer Engineering, University of British Columbia, Vancouver, BC, Canada
d. Department of Physics and Astronomy, University of British Columbia, Vancouver, BC V6T 1Z1, Canada; Canada Department of Electrical and Computer

The resolution limit in an EBL (electron beam lithography) process depends on the resist (and associated development process), substrate, the proximity effect, and the e-beam writer itself [1]. Since the resist process and the e-beam writer are generally standardized (cold development has been shown to improve resolution, however at the expense of much higher base dose [2]), proximity effect correction (PEC) provides the main path for improving resolution of an E-beam lithography process. In this work we look at using shape proximity effect correction (Shape-PEC) to improve the process window of a ZEP520A process on silicon on insulator (SOI) samples. We also analyze the underlying mechanism of this improvement, by simulating variations of the effective-blur [3] by utilizing Shape-PEC.

BEAMER by GenISys was used for preparing EBL pattern files and applying Shape-PEC. The target pattern required a 500 nm thick ZEP520A layer, so that the underlying Si layer can be subsequently etched at dimensions down to a few tens of nanometers. The target pattern is a photonic crystal nanocavity, consisting of periodic holes with nearby narrow trenches as shown in Figure 1 (a) [4]. This pattern is challenging due to the requirement of thick resist and having small features (trenches 20 nm and upward) adjacent to relatively large features (periodic holes are 210 nm in diameter). Shape-PEC thus becomes critical for achieving required resolution to correctly resolve this pattern [5].

To understand the impact of Shape-PEC, simulations were conducted. By corroborating the exposure latitude information to the simulation gathered from the 30 and 50 nm critical features (as shown in Figure 1 (b)), the effective blur was determined to be 40 nm. When analyzing the absorbed energy using the 40 nm blur, limitations and improvements to the process were better understood and thus utilized to improve the process, leading to improved resolution.

Figure 2 compares the SEM images of EBL runs with (i) no PEC, (ii) Long-range PEC only, (iii) Long- and short-range PEC and (iv) Shape-PEC applied on a relaxed design and (v) Shape-PEC on the original design ,with a larger gap between trenches and holes. It is evident from these experiments that Shape-PEC is able to render well this challenging pattern, while both long- and short-range PEC were not successful.

[1] K. Keil, *et al.*, JVST B **27**, 2722 (2009)
[2] C. Eichfeld, *et al.*, JVST B **32**, 06F503 (2014)
[3] L. Ocola, *et al.*, JVST B **33**, 06FD02 (2015)
[4] J. Wu, *et al.*, *IEEE Photonics Society Summer Topical Meeting Series*, HI, 2018, pp. 85-86 (2018)
[5] G. Watson, *et al.*, JVST B **15**, 2309 (1997)

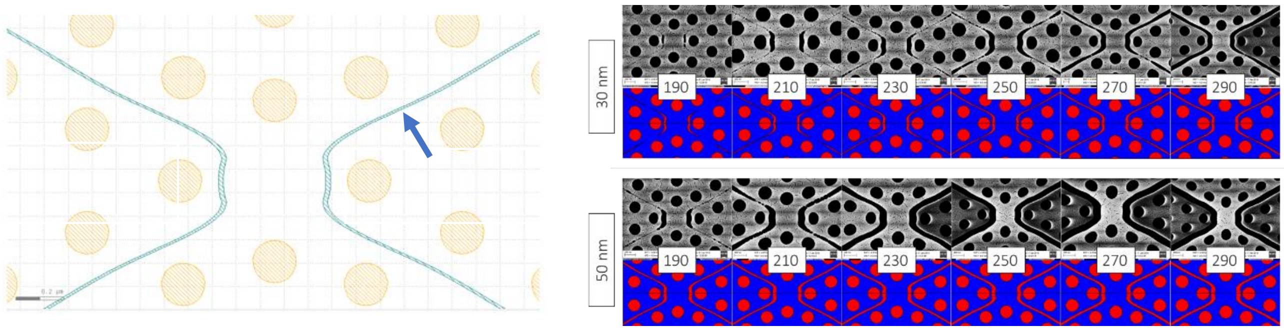

Figure 1. (a) CAD of the target design, periodic array of holes with 20nm wide trenches nearby. (b) Beamer simulations to determine blur at various base doses (in µC/cm^2)

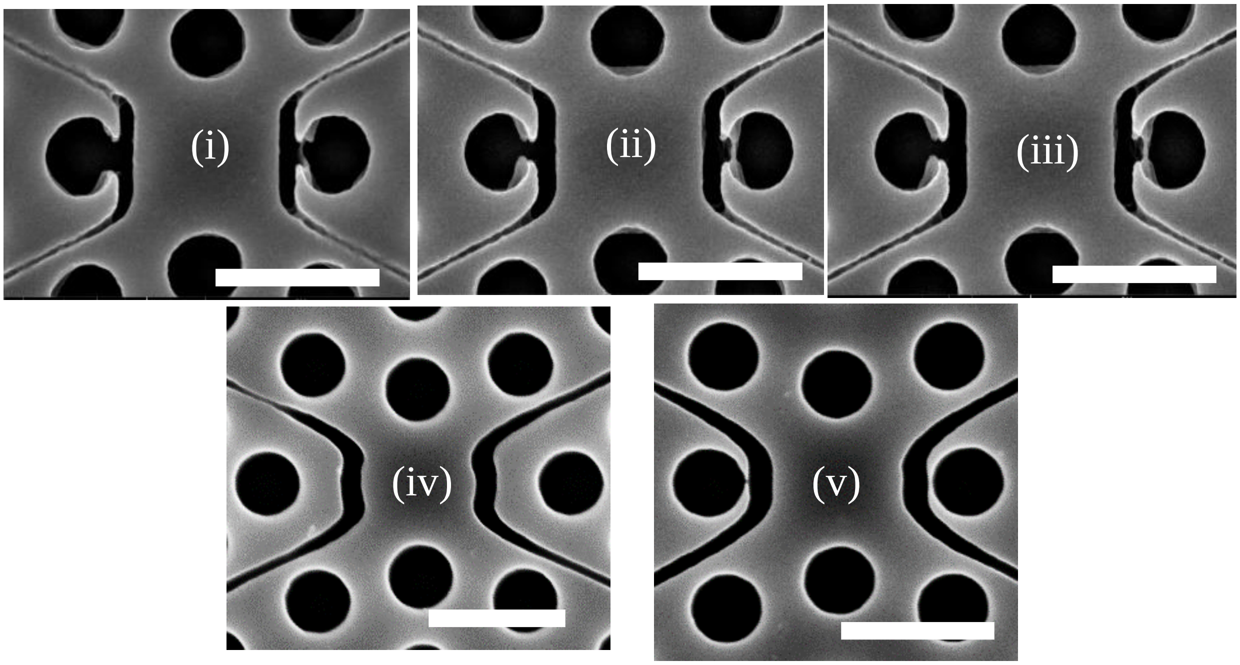

Figure 2. SEM images showing the results of various types of PEC. All scale bars represent 500nm, first three images are of resist only, with iridium coated for charge dissipation, whereas last two images show the structure after plasma etching of the silicon layer and removal of residual Zep520a. (i) No PEC, (ii) Long-range PEC only, (iii) Long- and short-range PEC, (iv) Shape PEC on relaxed design and (v) Shape PEC on original design.