# Bulk and sleeve electron beam lithography for silicon nitride photonic crystals

Mohammad J. Bereyhi[1]

[1]*Institute of Physics (IPHYS), Swiss Federal Institute of Technology Lausanne (EPFL)*

This is a method to improve the quality of lithography - in particular electron beam lithography (EBL). During an EBL exposure the electrons undergo different scattering processes. One scattering process that plays an important role is the back scattering of the electrons from the substrate or different stacks of thin film present in the exposure stack. As a result the actual dose that the resist sees is quite different that the original exposure dose. This difference can be fixed by means of proximity effect correction algorithms (PEC). In addition, the correction level that can be achieve via the PEC methods is limited to the absolute value of the dose and the back scattered electrons. As a result when the resolution is down to the limit of the resist, one might consider reducing the overall backscattered electron dosage by limiting the exposed area around the structure. Here we develop a process for making photonic crystals with high resolution EBL in silicon nitride.

Keywords: Lithography, Electron beam (EBL), Silicon nitride, photonic crystals

This technique is called bulk and sleeve and is used for positive resists e.g. ZEP that allow resolution down to 50nm and require careful exposure strategy. For a positive resist the exposed areas are dissolved in the developer and the unexposed areas act as a mask. The idea of bulk and sleeve method is to separate the exposed regions according to resolution. The total exposure area is broken down into two sub exposures: a sleeve around the high resolution structure (~1-2um width) and a bulk low resolution exposure for the rest of the exposed area of the resist which serves the purpose of only dissolving that area of the resist in the developer.

Here I give a simple but very practical example of a photonic crystal reflector:

Imagine you want to create a waveguide with photonic crystal holes using ZEP due to its high resolution and etch properties for etching SiN - this example is taken from hybrid OM transducer devices:

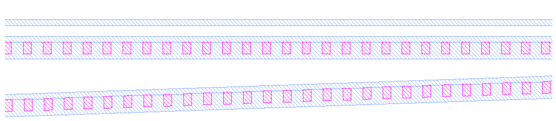

**Figure 1- Photonic structure to be written using EBL.**
Photonic crystal device designed for high resolution lithography. This shows the desired structure to be etched.

The problem arises when the rest of the PhC needs to be exposed and it generates extra backscattering dosage. So here we do a sleeve around the structure for 1.6 um width:

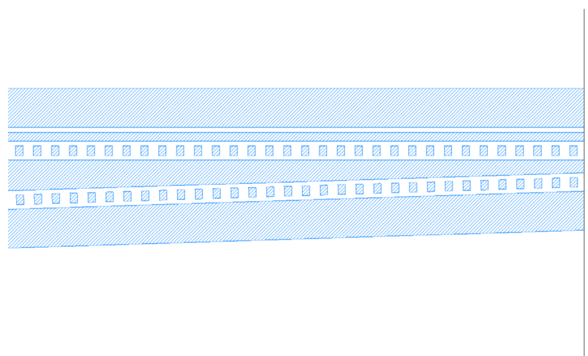

**Figure 2- Sleeve for EBL.**
Sleeve layer with 1.6um width around the desired photonic layer.

This is done using highest resolution required for the structure (here being 2na beam corresponding to 5nm spot size), this layer should ideally be etched and the rest of the structure is etched using a low resolution EBL of negative resist with a mask overlapping for 0.5 um with the current sleeve:

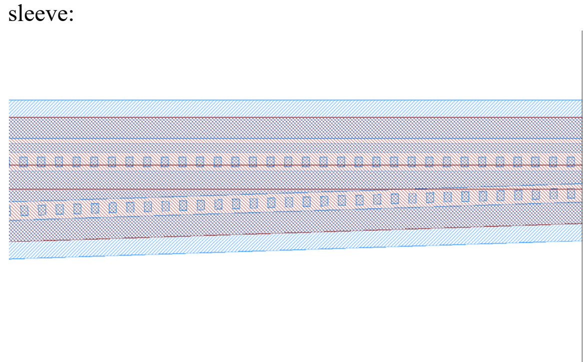

**Figure 3- Bulk layer on top of the sleeve for EBL.**
Bulk layer with 0.9um width around the desired photonic layer overlapped for illustration on top of the sleeve.

This way the lowest possible dose is used to do the lithography of the actual active part and the rest of the unwanted material can be cleared using a low resolution lithography. This method reduces the writing time and also the line edge roughness of the structures significantly.

Here I use 300nm of ZEP using 170 uc/cm2 dose to write and etch the sleeve layer and then I use FOX 16 of ~ 1um thickness to align to this layer and etch the rest of the SiN material:

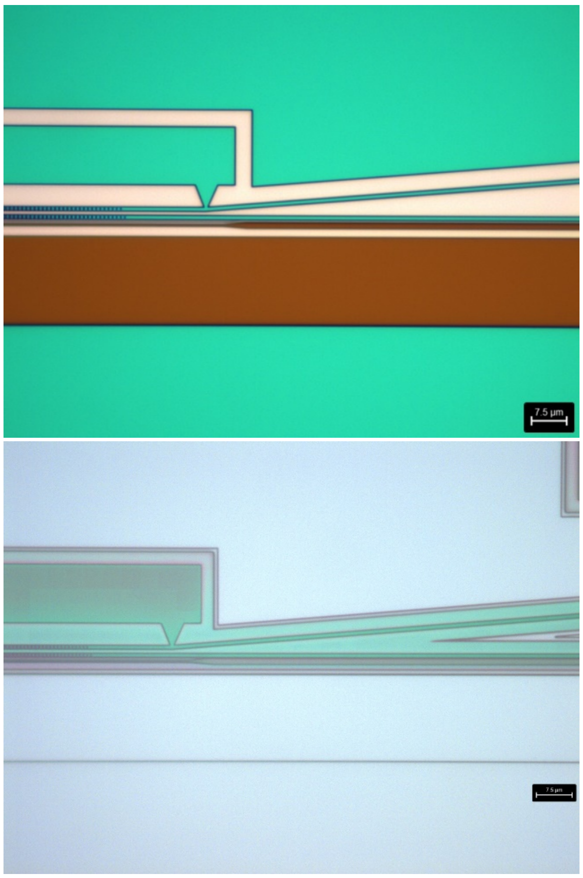


Figure 4- Sleeve for EBL with the bulk etched afterwards.

And for comparison reasons two similar design have been compared here to show the difference of the line edge roughness using the method and how smooth the lines and waveguides will be using this technique compared to conventional lithography:

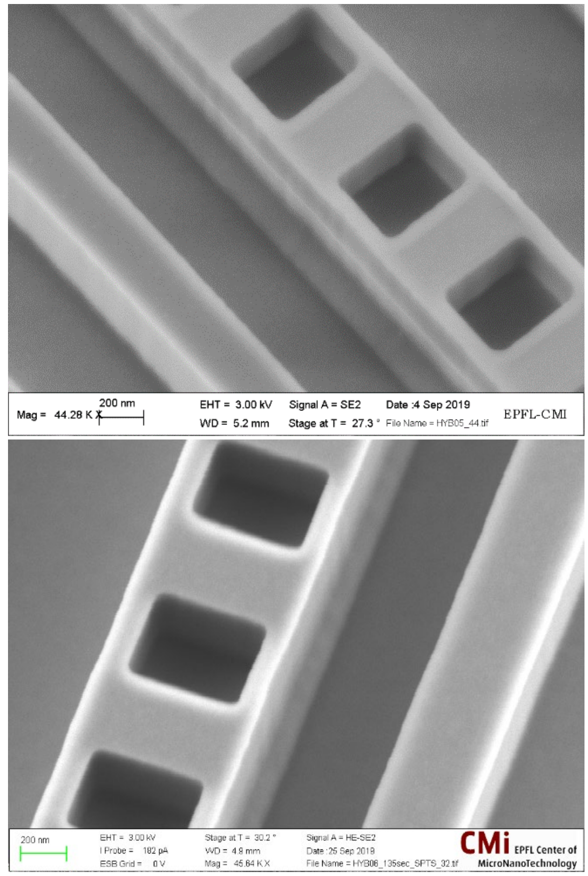


Figure 5- Top shows the conventional compared to bottom one using the bulk and sleeve method.