Intra-Level Mix & Match investigations of negative tone photoresists mr-EBL 6000.5 and maN 1402 for i-line stepper and electron beam lithography

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This paper presents the characterization of the two negative tone resists mr-EBL 6000.5 and ma-N 1402, from micro resist technology for an Intra-Level Mix & Match (ILM&M) approach. The ILM&M approach[1] combines multiple exposure technologies on the same resist layer, providing the advantage of resolving patterns of different dimensions with fewer process steps and shorter processing time. Since both resists are sensitive to both electron and UV radiation, process parameters for i-line lithography and electron beam lithography (EBL) need to be investigated to enable the ILM&M approach.
To determine suitable process parameters, a spin curve and post exposure bake (PEB) study were conducted for both exposure technologies. Additionally, the minimum feature sizes were investigated using a 500 nm thick resist layer for mr-EBL 6000.5 and a 200 nm thick resist layer for ma-N 1402. The impact of small feature sizes near the critical dimension (CD) limit of the used electron beam tool SB254 (shape beam) from VISTEC and the i-line stepper NSR2205i11D from NIKON on the residual resist thickness after development are investigated, considering the PEB.
Once all parameters were examined, they were combined for the ILM&M approach for specific lithography layers for carbon nano device (CND) applications in Fig 1 and photonic integrate circuits (PIC) applications in Fig 2. 50 % shorter exposure times of 3 hours (ILM&M) instead of 6 hours (only EBL) could be achieved.
The developed patterns were inspected using scanning electron microscopy (SEM), revealing dimensions with a 1:1 print for both EBL and i-line stepper lithography in relation to the layout (Fig 3).
Besides the ILM&M approach, resolution enhancement for the i-line stepper lithography is investigated. By reducing the exposure dose under the required dose for the 1:1 structure print, smaller structures down to 86 nm are obtained. This reduces the CD-limit of the used NIKON 2205i11D i-line stepper from 350 nm down to 86 nm (-75%). At the same time the resist thickness is reduced due to insufficient resist crosslinking degree. Due to the linear dependency of structure width to exposure dose, this process can be used for the deliberate realization of nanostructures below the CD-limit of such i-line stepper tools.

[1] Hofmann, Martin, et al. "Mix-and-match lithography and cryogenic etching for NIL template fabrication." Microelectronic Engineering 224 (2020): 111234.

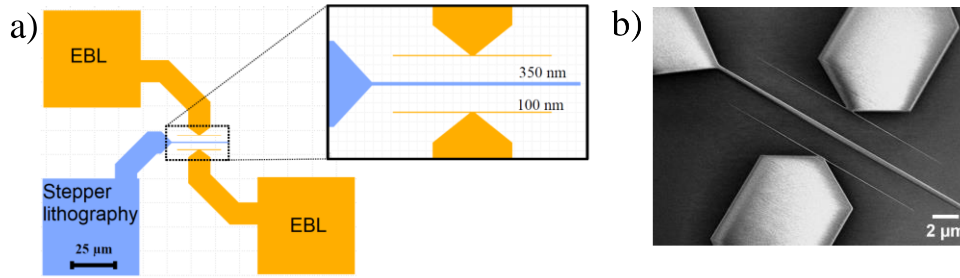

Figure 1: CND layout generated with maN-1402 by ILM&M approach.
a) Schematic view of the complex ILM&M layout, the orange structures are exposed with EBL and the blue one with i-line stepper, b) SEM image of the center region of this device rotated by 45 °.

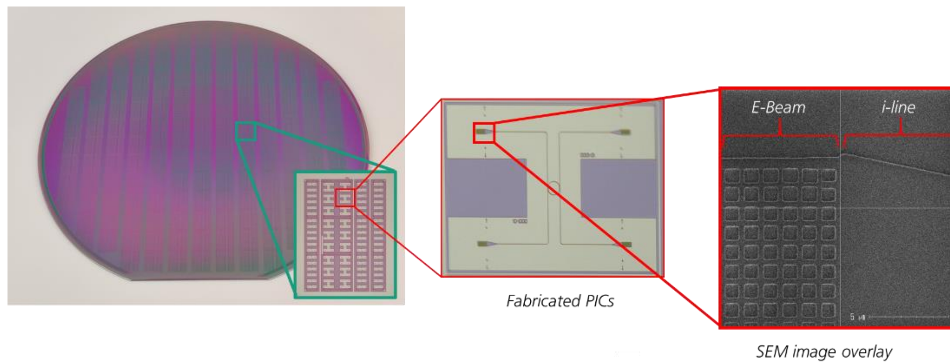

Figure 2: PIC ILM&M approach with mrEBL 6000.5: a) image of the processed 6" wafer with 150 dies, b) microscope image of one fabricated PIC, c) SEM image of the stitching area with EBL exposure (gratings) at the left and i-line stepper exposure at the right (waveguides and ring resonators).

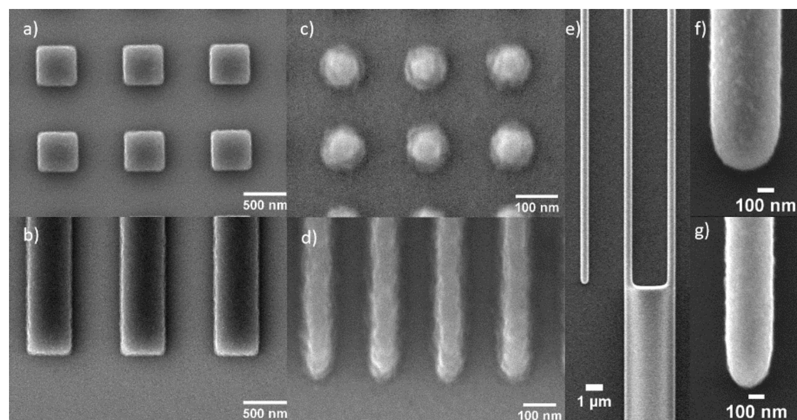

Figure 3: SEM images of EBL and i-line stepper lithography structures exposed in ma-N 1402. a) and b) shows the EBL exposed structures with 500 nm width, image c) and d) 100 nm structures. Image e) shows tuning fork structures with 500 nm dimension by i-line stepper lithography. Higher magnification is used for the imaging in f) and g) to demonstrate clear sidewalls on 500 nm and 350 nm structures after i-line exposure.