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PROOF-OF-CONCEPT EXPERIMENT REPORT

OPTIMIZATION OF THE ILLUMINATION IN THE LASER LITOGRAPHY PROCESS

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Proof-of-Concept experiment details

Received sample:

We have received the following sample: photoresist ma-P 1275 G.

Description of the problem by company:

In the process of laser lithography, different photoresists are used depending on the needs of the application. Each photoresist and the thickness of the photoresist application requires precisely adjusted parameters of laser illumination. The shape of individual illuminated geometries must be adjusted for optimal results. Optimization of illumination parameters in the laser lithography process for the purpose of the lift-off process requires extensive testing of illumination parameters (intensity, time, overlap, focus offset in the vertical direction, pattern and overlap width at field stitches). The result of an individual set of parameters is a structure in the photoresist that needs to be analysed qualitatively.

Main aim of the proposal:

Main aim of this proposal is to investigate stitch patterns with FIB. This will enable the company to understand the quality of their product and, more in general, to verify if the FIB+SEM approach is suitable and effective in the quality assessment of their samples.

Planned analysis:

After the photoresist illumination (see Sample preparation) testing of stitches with focused ion beam (FIB) technique will be performed. With cross-sectional analysis shape, width and depth of the stitches will be assessed.

Sample preparation:

Testing of stitch in photoresist ma-P 1275 G:

Combinations of 3 different stitch patterns. We have illuminated the pyramid, the horizontal and vertical lines of thickness 5, 10 and 20 µm (Fig. 1)

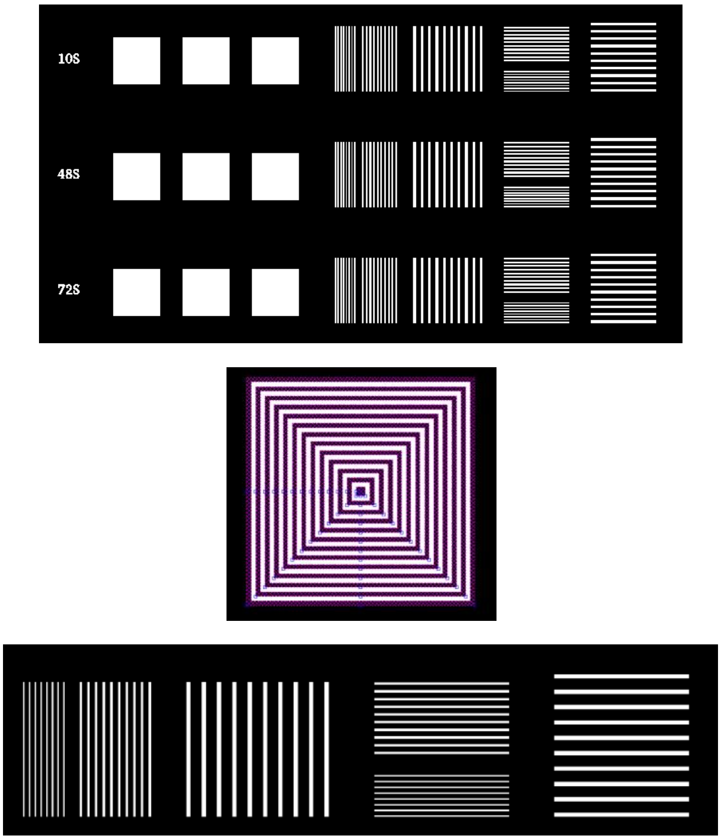

Figure 1: An image of patterns in the DaLI software:

Table 1: Type of patterns and gaps used

Type of pattern	Line/gap (µm)
Pyramid	10
Line nr.1	5/25
Line nr.2	10/30
Line nr.3	20/60

Basics:

- # = comment oz. inactivated command
- 0 = pixel not illuminated
- 1 = pixel is illuminated
- illumination.overlap.extend.pattern = = function defines the overlay mode
- extend - how far we go beyond the current scanfield
- inside - how to illuminate in the border area of the current scanfield, if not defined, the default extend pattern is the same as extend pattern
- If in extend and inside 1 is in the same place, it means that this pixel is illuminated twice.

We tested the following 3 stitch combinations:

1) 10 steps:

- illumination.overlap.extend.pattern=1010101010
- illumination.overlap.inside.pattern=0101010101

2) 48 steps, 3 intensities:

- illumination.overlap.extend.pattern=011110111101111010100101100101101000010000100001
- illumination.overlap.inside.pattern=100001000010000101011010011010010111101111011110

3) 72 steps, 8 intensities:

- illumination.overlap.extend.pattern=111101111110111011110101011100111001011000110001010100001000100000010000
- illumination.overlap.extend.pattern=111110111110111101110101011100111001011000110001010100010000100000100000

Parameters for photoresist:

- Substrate: Si-wafer
- Photoresist: ma-P 1275 G
- Spin coating: 60 s, 3000 rpm
- Soft bake: 100 °C 11 min
- Exposure: Pyramid dose med 10-490; lines 50;
- Development: mr-D 526/D: 3min 40s, rinsing with deionized H_2O

Measurement author and place:

Photoresist samples were prepared and illuminated by Maša Klenovšek and Damjan Svetin in Nanocenter. Cross-sectional analyses were performed on by dr. Bojan Ambrožič with FIB FEI Helios NanoLab 650 in Nanocenter.

Observation conditions:

Imaging: beam energy 1-30 KeV; secondary electron detector, backscattered electron detector. Cross-sections from the selected regions on the sample were obtained after deposition of a thin layer of platinum on the surface (first 0.2 µm thick layer at 2 kV, 0.4 nA, second 1 µm thick layer deposited at 30 kV, 0.24 nA), followed by cutting the coating using Ga FIB beam at 30 kV, 9.4 nA. In the end, the surface was polished with Ga beam at 30 kV, 0.4 nA. Imaging along cross-section was performed by SEM using SEI mode at 5 kV energy, 100 pA.

Results

FIB samples: with 10 steps (sample 10S), 48 steps (sample 48 S) and 72 steps (sample 72S) were analyzed. With FIB cross-sectional analysis (Fig. 2, Fig. 4) it was found out that samples with more steps have longer and shallower stitch and samples with less steps have deeper and narrower stitch (more details in Table 2).

Sample 10S:

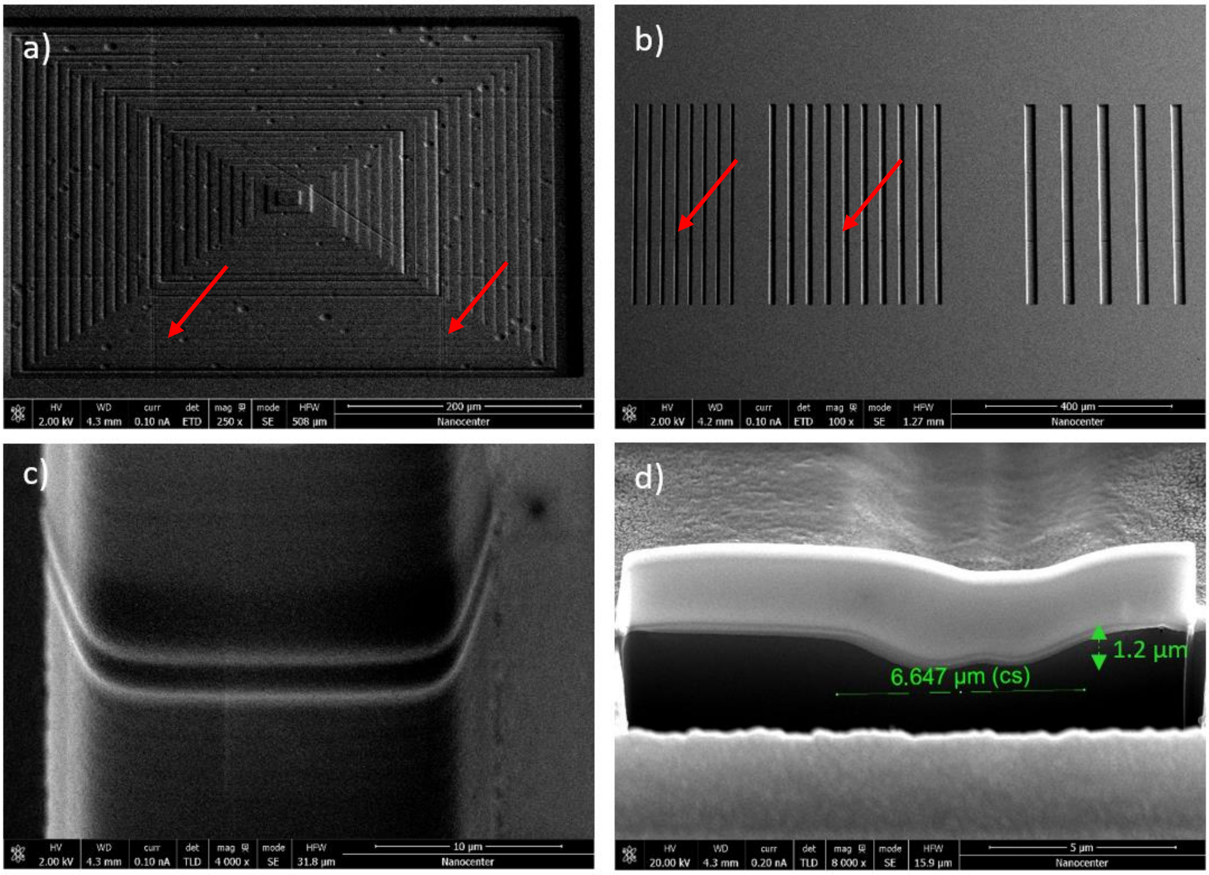

Fig 2. FIB analysis of stitches in sample 10S: a) pyramid pattern with indicated stitches, b) line pattern with indicated stitches, c) 4000 x magnified image of single stitch in line pattern, d) FIB cross-section across stitch with measurements of the width and depth of a stitch.

Sample 48S:

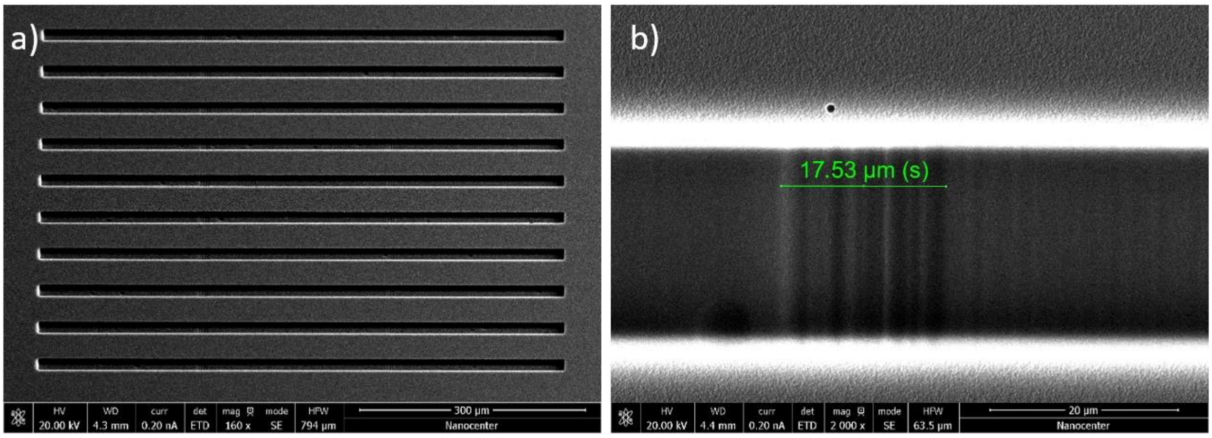

Fig 3. FIB analysis of stitches in sample 48S: a) line pattern with indicated stitches, b) 7000 x magnified image of single stitch in line pattern

Sample 72S:

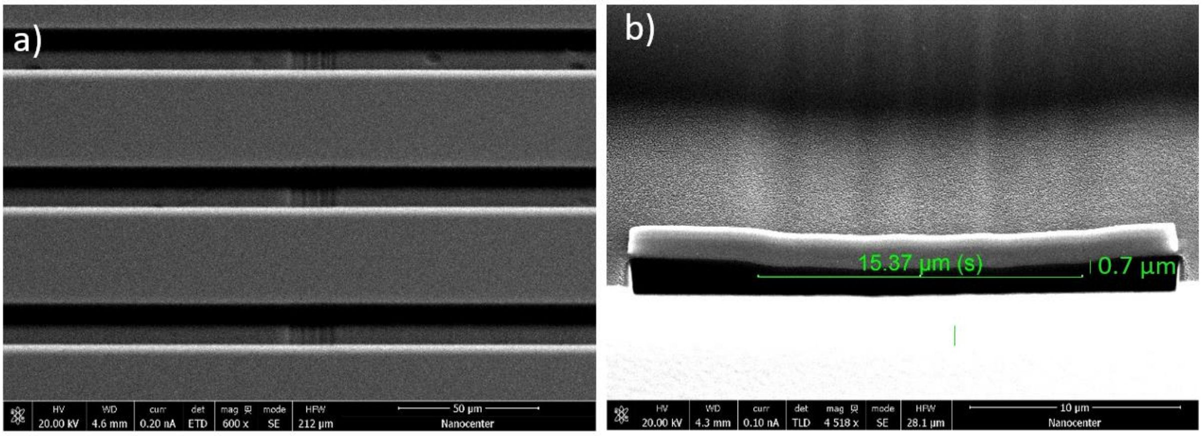

Fig 4. FIB analysis of stitches in sample 72S: a) line pattern with indicated stitches, b) FIB cross-section across stitch with measurements of the width and depth of a stitch.

Summary

With FIB: samples with 10 steps (sample 10S), 48 steps (sample 48 S) and 72 steps (sample 72S) were tested. It was found out that samples with more steps have longer and shallower stitch and samples less steps have deeper and narrower stitch (Mode details in the Table 2).

Table 2: Length and depth of stitch as function of the number of sample's steps.

Sample	Length of stitch	Depth of stitch
10S	6.6 µm	1.2 µm
48S	9.6 µm	/
72S	15.4 µm	0.7 µm

Final remarks about the effectiveness of the FIB+SEM approach

The use of FIB X-sectioning and the investigation by SEM is effective in the characterization of this kind of laser-lithography samples, and suitable for the assessment of their quality.

This report has been written by **Bojan Ambrožič** (Ljubljana, 18th May 2021).