Study of digital level exposure at BL-5

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INTRODUCTION

In this research, multiple overlapped exposures were performed and those developed depth were investigated. X-Ray lithography can be employed for fabricating optical device, because the X-Ray lithography can produce high aspect ratio and three-dimensional structures in micro/nano scale [1]. Although three-dimensional structure was produced utilizing PCT technique [2], available structure shape was restricted. In the case for fabricating an optical element, important factors are shape correctness and surface conditions. The width of structure is determined mainly by a shape of mask and the influence of diffraction, and the height of structure is determined by dose amount and developing time. We can obtain the multilevel step structure using with multiple overlapped exposures. If a multi-level element is used for optical device, it is higher efficiency than the two level one, and it is possible to produce a structure which has planar free design. For example, they are a Fresnel lens, a Holographic Optical Element (HOE), and so on. So, in this research, the difference in the height of each step when performing multi-level exposure was investigated.

Exposure system

An exposure system for a nanoscale resolution particularly used for a dynamic exposure with a high precision exposure stage has been installed in BL-5 at AURORA. Fig. 1 shows a photo and a schematic dimension of exposure stage system which provide flexible multipurpose for conventional 1-to-1 direct exposure, PCT technique, and variable proximity double exposure [3]. An exposed PMMA (Polymethyl-methacrylate) resist was developed by GG developer. The developed depth related with each dose amount was shown in Fig. 2. From this graph, a margin of error in height was less than 5% when dose amount was less than 0.015 A·h, the margin of error was about 30% when dose amount was more than that point.

Experimental result

4 times and 9 times multiple overlapped exposures were performed, used with mask pattern of 10-μm-square and its proximity gap (the distance from mask to resist) was 50 μm in each exposure.

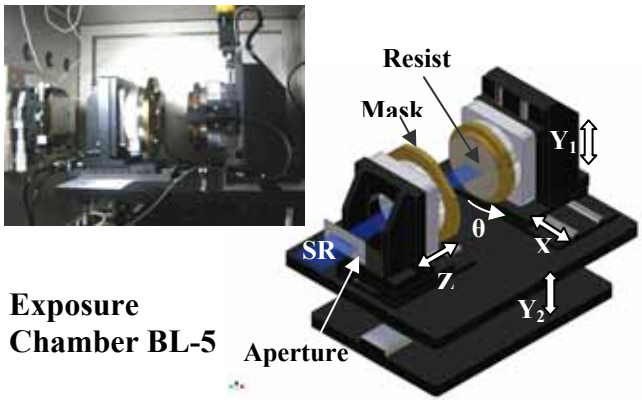

Fig.1 Multi-functional exposure stage

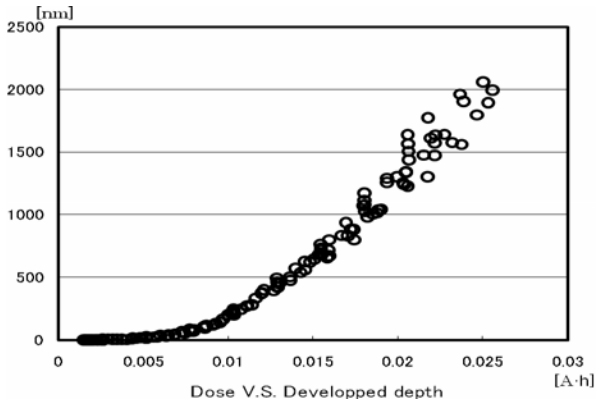

Fig.2 Graph of developed depth

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When the 4 times overlapped exposures were performed, the 4 stage positions were stepped moving by the sequence 1st to 4th as shown in Fig. 3. Each moving steps were 5 μm in X axis or Y_1 axis, and dose amount was 0.00675 A·h in each step as digital level. In the same sequence, the 9 times overlapped exposures were performed as shown in Fig. 4, the each moving steps were 3.3μm and dose amount was 0.003 A·h. The structures were measured by Scanning Probe Microscope (SPM) and the results were shown in Table 1 and 2. The results of processed depth were normalized and indicated to the table. As shown in Table 1, each steps are almost same level, actually the depth error margin were less than 5 nm, and about surface roughness, each Ra was 18 nm when the 4 times overlapped exposures. About the 9 times overlapped exposures, as shown in Table 2, the depth error margin was about 20 nm when over 6 times exposures, though Ra was 12 nm. All developed depth were based on the Fig. 2.

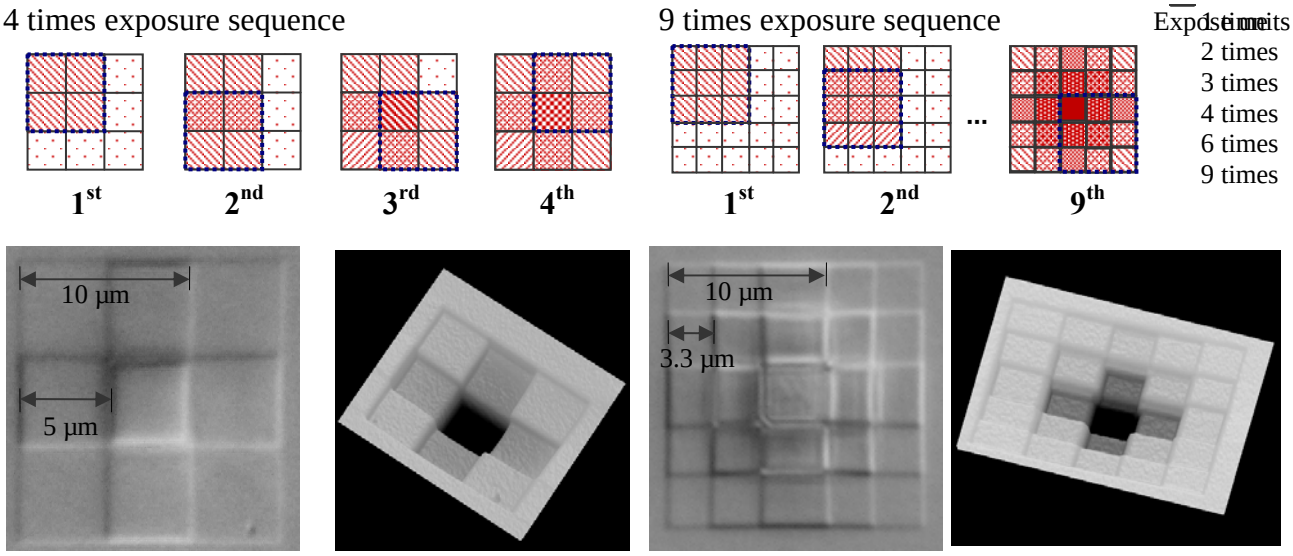

Fig. 3 4 times overlapped exposure

Fig. 4 9 times overlapped exposure

Table 1 Result of 4 times overlapped exposures

1.0	2.0	1.0
2.0	6.1	2.0
1.0	2.0	1.0

Table 2 Result of 9 times overlapped exposures

1.0	2.2	4.0	2.3	1.0
2.2	6.0	13.0	6.1	2.2
3.5	12.5	28.0	12.5	3.6
2.3	6.0	12.6	5.9	2.2
1.0	2.2	3.7	2.2	1.0

CONCLUSION

4 times and 9 times multiple overlapped exposures were performed, and successfully 5 steps and 10 steps structure were fabricated each other. Each level error margin and surface roughness are very small, and it turned out that it is about less than 10% of the wavelength of visible light. However this results is not the "digital level structure" but the "digital level exposure", we have to improve the process to achieve digital level structure.

REFERENCES

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