Performance of Multi-directional SR-exposure Stages for Micro/Nanofabrication at BL-5

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Recently, the microfabrication of arbitrary shapes of curvature and sloped sidewall structures has been succeeded using conventional SR lithography with Plane-pattern to Cross-section Transfer (PCT) technique developed at Ritsumeikan University [1]. In fact, the technique was still not for nanoscale while using the existing beamlines at the AURORA. Therefore a new exposure system for a nanoscaled resolution particularly used for a dynamic exposure with a relatively accurate movement of the stage has been installed. The development of systems for the exposure which facilitate the precise positioning, stepping and repeatable were reported [2, 3]. However, the multi-functional stage is still hardly available. Although the AURORA storage ring has 3 more beamlines working for SR lithography, only the beamline-5 (BL-5) can challenge the nanomachining technology especially for the arbitrary 3D-structures.

Figure 1 shows a combination of working stages X, Y_1, Y_2, Z, θ which provided the flexible exposure system for stepper(X, Y_1, Z, θ) and PCT (Y_2, Z, θ) exposures individually or all at once by programming. The specifications of the stage system are listed in Table 1. X, Y_1, Z and θ stages were assembled on Y_2 stage which was designed to serve the PCT exposure. The precision of this multi-functional stage was observed by twice exposures through a square mask pattern of 10 μm with the moving stage distance of 10 μm in order to see whether the pattern are totally aligned and connected. The result is plotted in Figure 2. The actual resolution of our stage system was less than 150 nm.

Using the same mask as the above test of stage precision to process a half size of the actual mask, 4 stepping position of the stage were experimented by the sequence 1^{st} to 4^{th} as shown in Figure 3. The actual positions of stage were observed by the images taken by Atomic Force Microscope (AFM). Figure 4 illustrates the results after exposure and developed. The resolution of 150nm enhances the possibility in fabrication of 3D-nano optical devices such as Wavelength Division Multiplexing (WDM) device, Diffractive Optical Element (DOE), Sub-Wavelength Structure (SWS), and so on.

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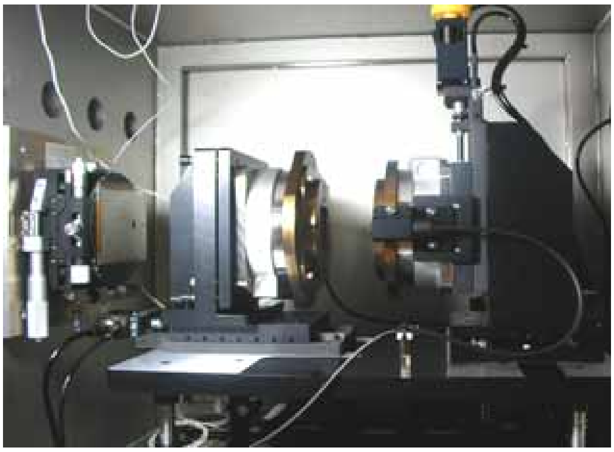

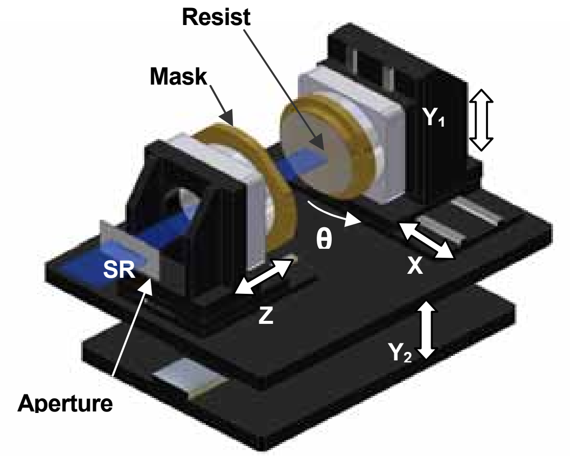

Fig.1 Multi-functional exposure stage at BL-5

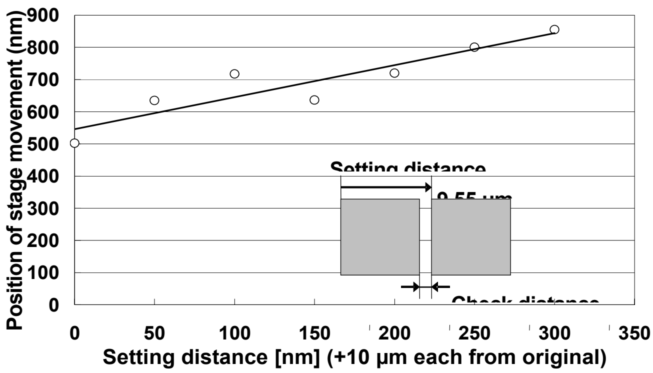

Fig. 2 Plotted result from stage movement test

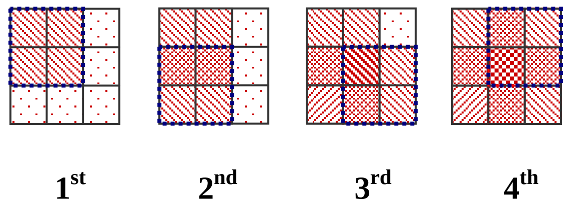

Fig. 3 Sequence position of step-exposure

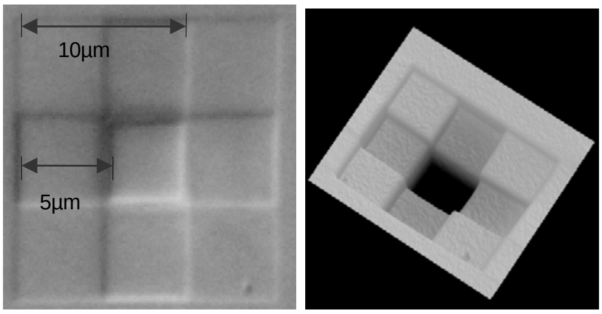

Fig. 4 Images of stepper exposure results

Table 1 Exposure stage specifications

Stage Item	**Specification**
X axis	±50 mm
Y_1 axis	±25 mm
Z axis	50 mm
Y_2 axis	±25 mm
expected resolution	50 nm
mask-resist gap	0 to 50 mm
error	<120 nm

References

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Pattern-formation Technology for Arbitrary 3D Structure Using SR Lithography

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This paper reports a research on establishment of the new fabrication technique of three-dimensional microstructure using SR (Synchrotron Radiation) light. Formerly, some works of the three-dimension processing method using SR light have been already reported [1] [2] [3]. These reports are the techniques of giving exposure energy distribution to the resist surface. However, it is difficult to fabricate arbitrary form with these existing technologies. For example, suppose that complicated form e.g. human's face is fabricated in a 1 mm x 1 mm area. For that purpose, quite complicated energy distribution has to draw on a resist. Depending on a target form, complex images can be considered with the existing technology. However it is necessary to prepare a number of masks, the initial cost and complicated process cost are the obstacles. Consequently, we have researched on a novel processing method for making the total image form single mask pattern.

As a concrete method, to give energy distribution to the resist surface in the shape of a mosaic is examined using the beam through a square mask pattern operated. PMMA (Polymethylmethacrylate) resist is irradiated with mosaic-like energy distribution as shown in Fig. 1. A free curved surface and a side wall inclination are fabricated using etching mechanism of PMMA being carried out to isotropy. The structure which actually gives energy distribution using the mask pattern which has a 100 μm line and has a free curved surface was fabricated (Fig.2). Moreover, exposure using PTFE (Polytetrafluoroethylene) resist was also performed. Since PTFE does not need a development process, it can be predicted that difference level structure etc. is producible. Figure 3 shows the direct etched PTFE structure.

In order to enable fabrication of arbitrary form freely, establishment of processing technology will be indispensable from now on. As a future work, researches of the system which shape-prediction from energy distribution and exposure by smaller line width are due to be performed.

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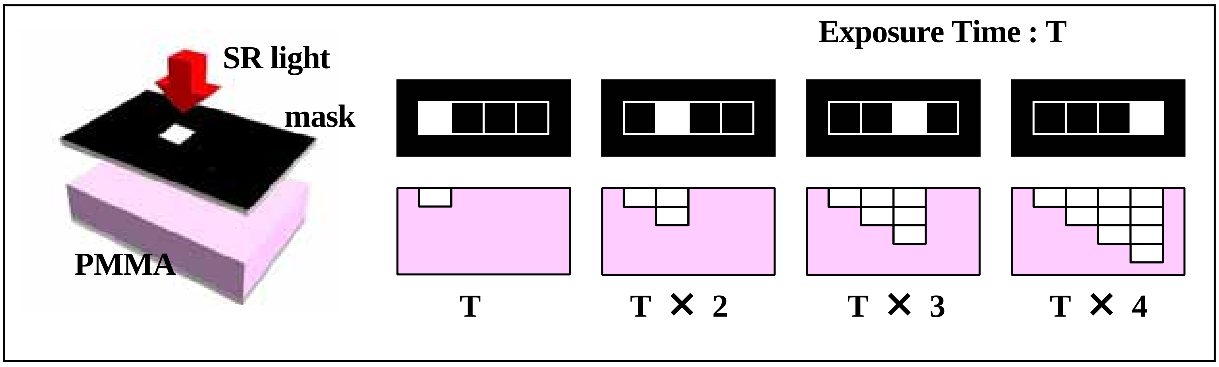

Fig.1 fabrication outline

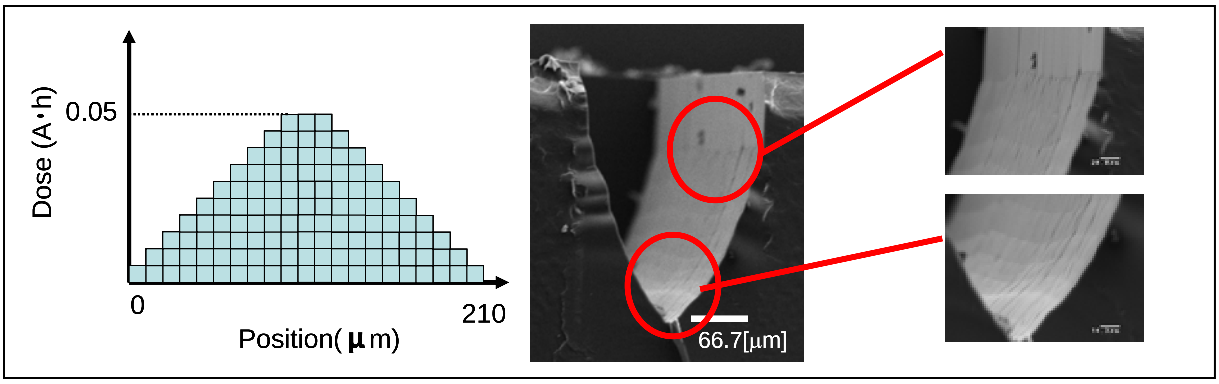

Fig.2 energy distribution and fabricated structure

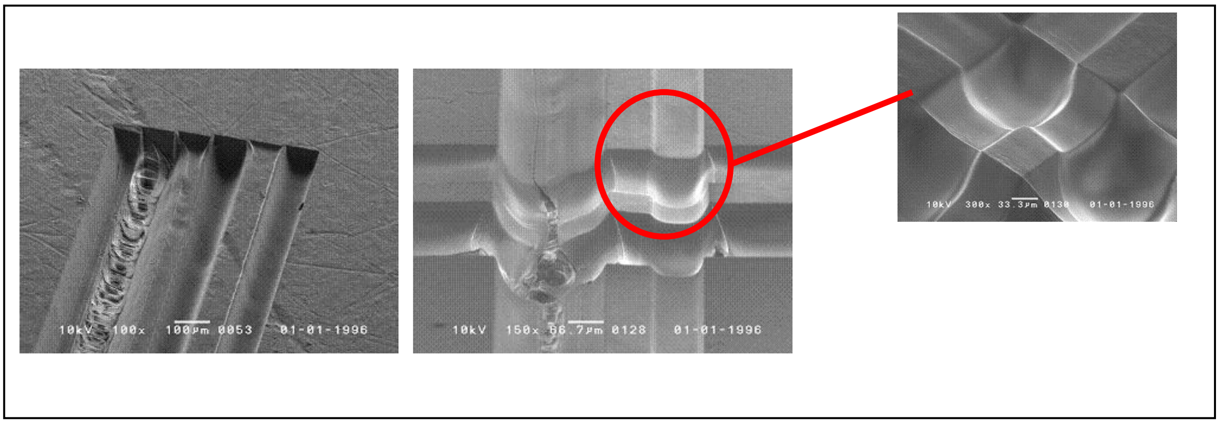

Fig.3 SEM images of PTFE structures

References

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