Research of New Technology for Arbitrary 3D Structure Using SR Lithography

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Abstract

This paper is reported a research on establishment of a newly fabrication method of three-dimensional microstructure which used SR (Synchrotron Radiation) light. This method has some advantages. Especially, there are two advantages which make to rapidly progress to needs-oriented technology. One is possible to give complicated energy distribution, another is not necessary to manufacture a mask for every form. Our research has advanced for the purpose of attaining these two advantages. This method has just still started recently. Therefore many problems also still exist. In this time, it is reported about fabrication of mask for beam forming, driving method of stage for exposure, and three-dimensional structures by using this method.

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1. Introduction

A variety of three-dimension processing technologies such as KOH anisotropic etching of silicon and laser machining[1] have been employed for fabrication of Micro Electro Mechanical Systems(MEMS). Especially, 3-dimension fabrication that uses X-ray lithography in LIGA (Lithographie, Galvanoformung, Abformung)[2] [3] [4] [5] [6]. LIGA draw attention from widely research area as technique that can fabricate structure that has controllable 3-dimensions with respective height.

Before now, some research of three-dimension processing methods using SR light is already reported [2] [3] [4]. Each of these is techniques of giving exposure energy distribution to a resist surface. In order to fabricate arbitrary 3-D structures, complex energy distribution need to give to resist surface

However in order to use such technology, special equipment and expensive X-ray masks are required. In addition, if we use these methods, it is not easy to fabricate arbitrary form. Then, we have been advancing research of the new processing method for making all form from one mask pattern.

For example, suppose that complicated form like people's face is fabricated in a 1mm x 1mm campus. For that purpose, it has to give quite complicated energy distribution to resist. Depending on target form, an impossible thing can be considered with the existing technology, or since it is necessary to also prepare many masks, it is also expected that cost starts and processes are complicated.

As a concrete method, how to give energy distribution to a resist surface in a 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.

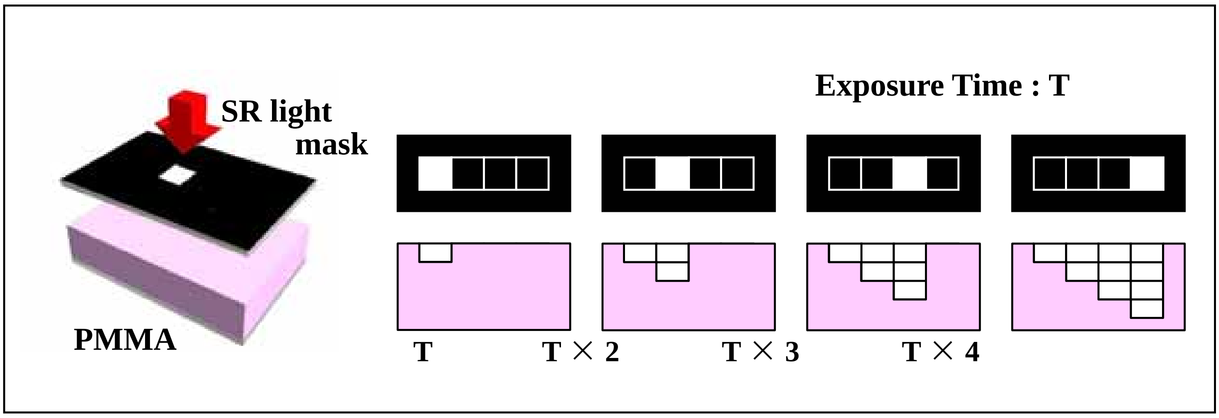


Fig.1 fabrication outline

2. Fabrication and Experimental Conditions

A number of experiments were carried out using beam line number 13 and 15 (BL-13, 15) at the superconductivity compact synchrotron radiation (SR) source "AURORA", at the SR center, Ritsumeikan University, Japan. The properties of SR at AURORA are, wavelength of 0.15 nm range to visible light range, applied electron energy and the maximum storage current in the experiment were 575 MeV and 300 mA, respectively. The light from AURORA penetrates two 200 μ m Be windows, and uses within the chamber the light which has a 0.15 to 0.95nm wavelength domain. The exposure environment was covered with Helium gas at 1 atm in the chamber in order to prevent the attenuation of X-ray by N_2 or O_2 gases and to prevent damages of the mask or resist by heat generated. PMMA was used as a resist. Since a resolution of PMMA is high, a reproducibility of fine structures for molding can be enhanced as the further fabrication process [7].

2.1 Experiments using BL-13

In order to experiment for giving mosaic-like exposure energy distribution to the resist surface, stage program was made to improve with C++ programming language. An improvement of this new stage program contains not only driving method of stage for exposure, but also loading current value and dose amount of AURORA. If we use this new stage program and input necessary dose amount to corresponding grid, the stage will be possible to automatically moved and expose next grid after the grid leach to necessary dose amount.

2.2 Experiments using BL-15

If we use existing stage program system of BL-15, it is possible to expose changing speed and acceleration. We tried to fabricate three-dimensional structures with this system. In addition, BL-15 has heater system. Therefore the resist, such as PTFE which needs heating can be exposed. Generally, in the PTFE fabrication process using SR ablation, it is noted that the etching rate becomes greater when PTFE is etched in a vacuum chamber and heated during the ablation [8]. It is possible to provide the vacuum atmosphere at 10^{-5}torr in the chamber of BL-15.

2.3 Fabrication of a mask for beam forming

This method is needless to fabricate a mask for every target form. However, the mask for beam forming is need. We fabricated this mask by LIGA process. Using the mask pattern (1500μm x 30mm) as shown in Fig. 2, it is exposed to move the mask to crosswise and lengthwise direction such as a fabrication of L/S, and pillars were produced as shown in Fig.

3. Process flow is shown in Fig.4 and the mask for beam forming which is fabricated is shown in Fig.5.

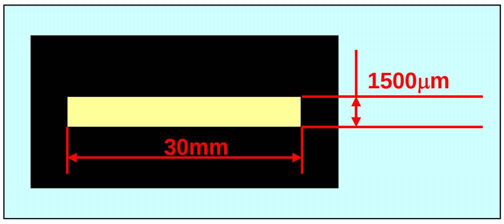


Fig.2 Mask pattern 1500μm x 30mm

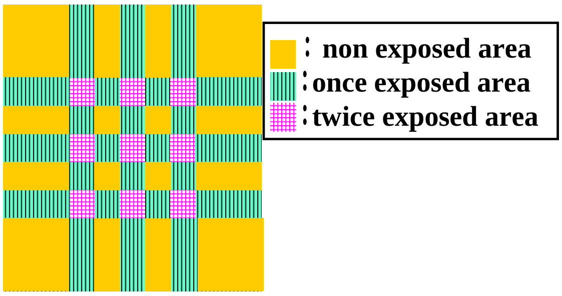


Fig.3 Image of expositing

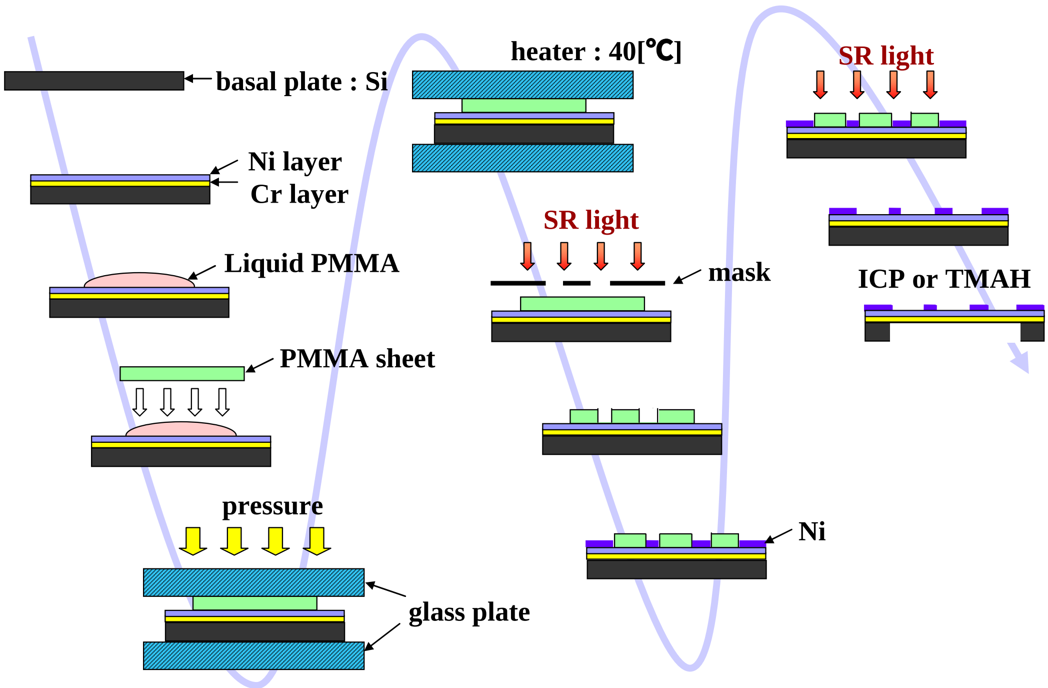


Fig.4 Process flow

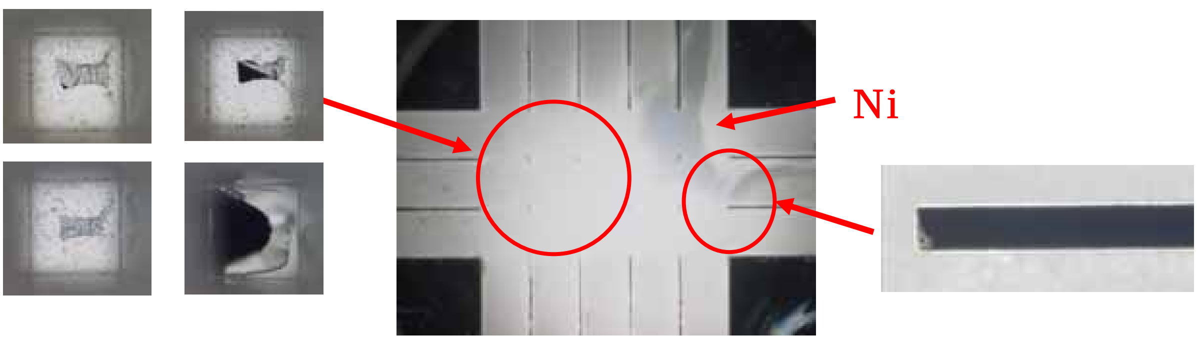


Fig.5 Mask for beam forming

4. Results

4.1 Mosaic-like exposure

Results which are a giving mosaic-like exposure energy distribution to a resist surface are shown in Fig.6. As shown in a figure, the structure in which the surface curved was fabricated. However, a stringy surface has appeared on the borderline of grids. It is necessary to make this line reduce from now on. As shown in Fig. 5, thin films remains in holes. If it is removed and using the high accuracy mask, we think that smoother surface is possible to be fabricated.

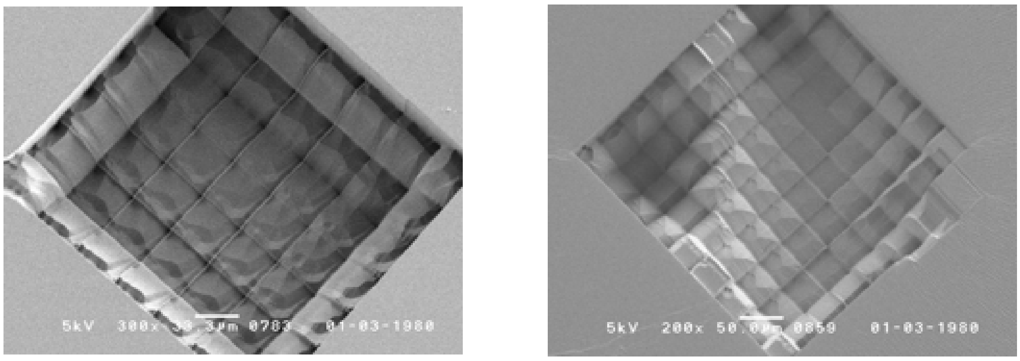


Fig.6 Mask for beam forming

4.2 Changing scan speed

When PMMA resists are exposed using a mask pattern of a rectangle, stage is scanning. And, in order to give an energy distribution to the resist surface, scan speed is changing. As shown in Fig.7, structures with curved side wall were possible to be fabricated. Since it exposed scanning, lines as shown in Fig. 6 did not appear.

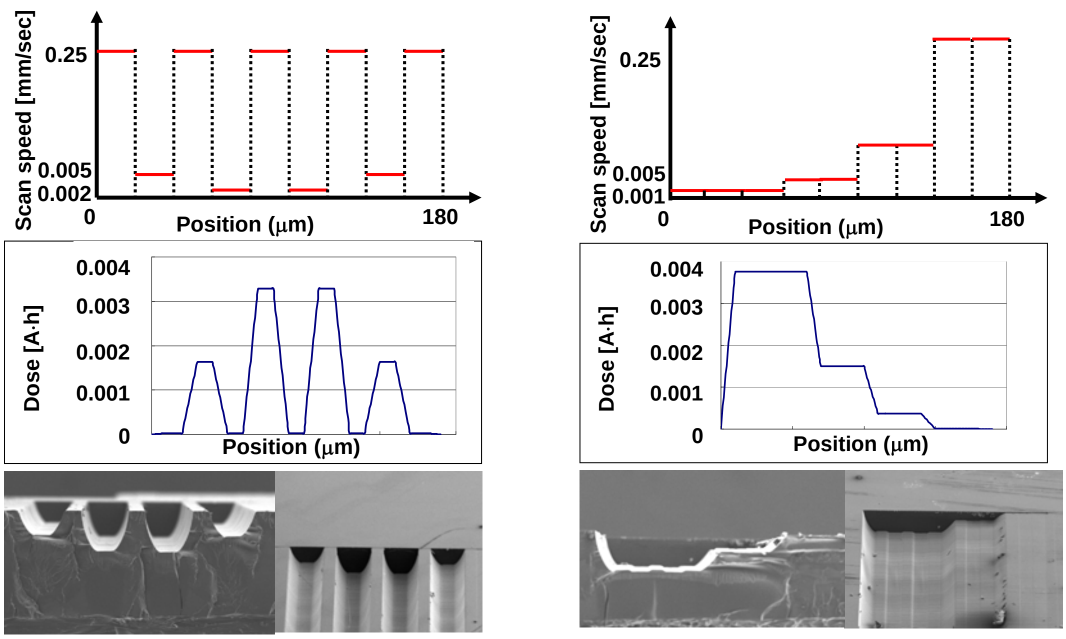
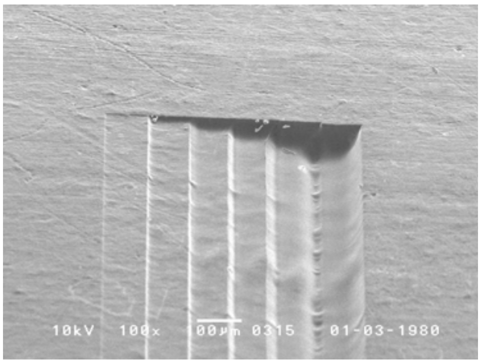


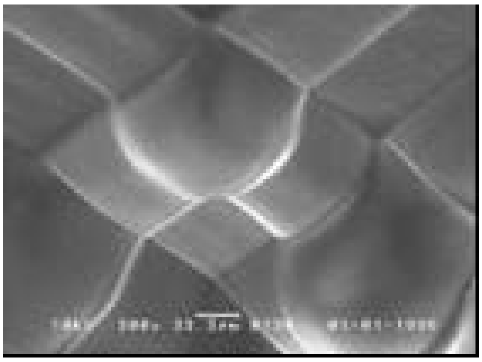
Fig.7 Scan speed, energy distribution, structures

4.3 PTFE structures

SR ablation does not need development process. Therefore, if it is given mosaic-like exposure energy distribution to a PTFE surface, stairs surface is possible to be fabricated. PTFE structures are shown in Fig.8.



Stairs surface



Bump surface

Fig.8 PTFE structures

5. Conclusion

We have been advancing research of a new processing method for making all form from one mask pattern. We fabricate a mask for beam forming, and some three-dimensional structures are fabricated. In the future, stringy surface have to change smoother surface. By uniting the results of 4.1 and 4.2, we think that it can be made possible.

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