Study on Newly 3-D SR lithography Fabrication Method Utilizing PDMS Mold

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Abstract

In this study, newly additional process of SR lithography is reported. Various methods have been developed for as an additional technique to enhance the three dimensional processing. 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. The purpose of this research is to fabricate a structure with difficult fabrication easily. The newly process was devised. If using this process, it can be reasonably expected that fabrication of a structure with difficult methods easily. This time, it focuses attention on PDMS as a material to fill. PDMS can be fabricated in a simple process, in addition molding and exfoliation have simply the advantage of being possible. Characterization of PDMS is checked. And, the structure is fabricated by using this newly process. However, the point where V-formation crosses was not successful. Some causes can be considered. Reasons of this result are checked. One of them, it is thought that micro-loading effect influenced. Therefore, it is necessary that change of processing depth to line width is checked. The processing depth becomes low as line width becomes small is checked.

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1. Introduction

A variety of 3-D fabrication methods 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. Various methods have been developed for as an additional technique to enhance the three dimensional processing. 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. The purpose of this research is to fabricate a structure with difficult fabrication easily. In this study, newly additional process of SR lithography is reported.

In this time, fabrication of a structure as shown in Fig.1 is aimed at. For that purpose, it is necessary to give energy distribution as shown in Fig.2. It is difficult to give such energy distribution with the existing technology.

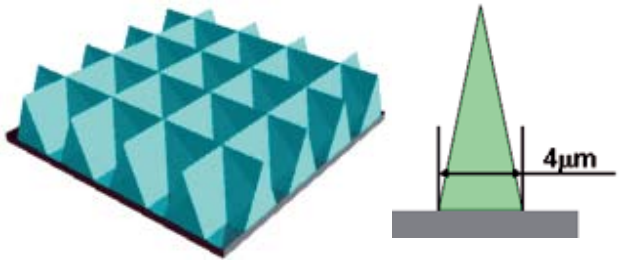

Fig.1 Target structure

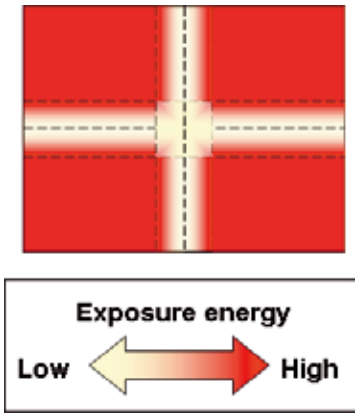

Fig.2 Energy distribution (Top view)

If Plane-pattern to Cross-section Transfer (PCT) technique is used, the structures with V-formation or chevron can be fabricated easily. PCT technique is one of the 3-D fabrication methods. Fig.3 shows the PCT technique. The energy distribution is deposited in resist by scanning as shown in the same figure. 3-D structures were fabricated by developing afterwards. When PCT technique is used, the similar shape as the mask absorber pattern in the mechanism is expected to be fabricated. In addition, a more complex energy distribution can be given by exposing it by rotating the mask by 90 degrees. The needle shape can be fabricated as an example of using PCT technique. This structure resembles target structure (Fig.2) very much. However, since the energy distribution becomes as it is shown in Fig.4 in this time, it can not be fabricated although it is very alike.

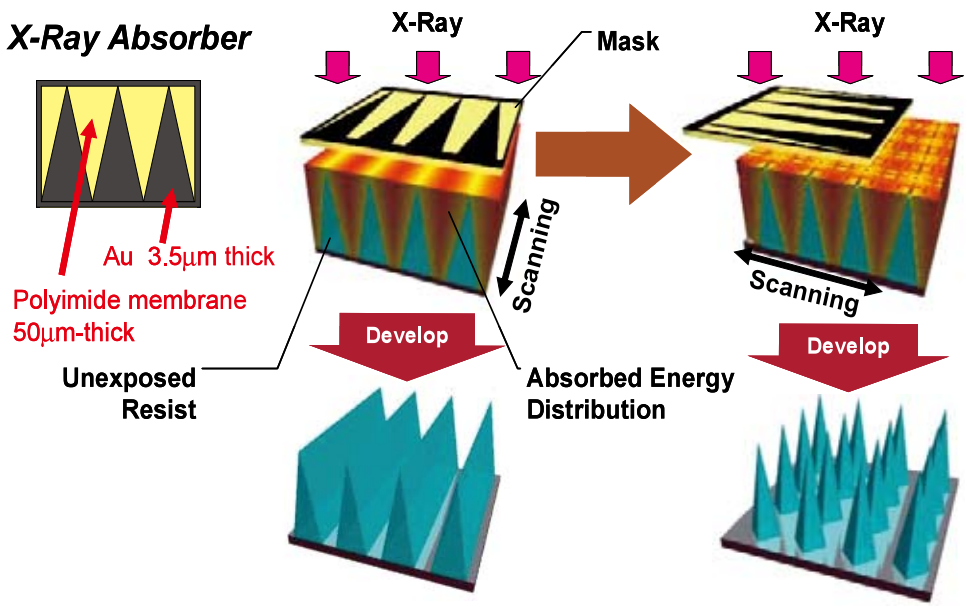

Fig.3 PCT technique

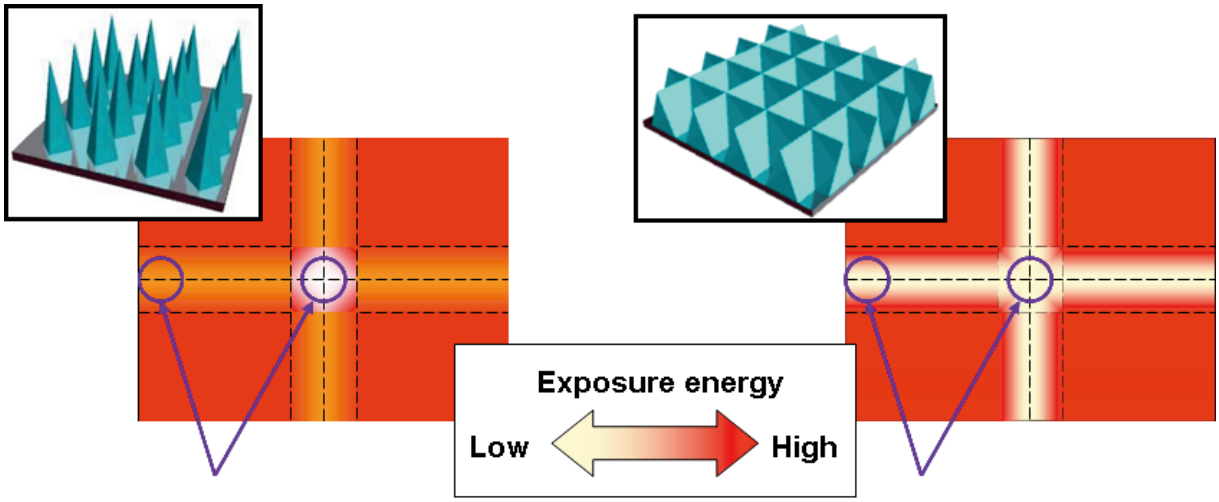

Fig.4 Energy distribution for shaping microneedle array and target form (Top view)

Therefore, the newly process as shown in Fig.5 was devised. First, the structure with V-formation is fabricated using the PCT technique. Next, fabricated V-formation is filled by something. Next, the structure with V-formation is also fabricated using the PCT technique by rotating the mask by 90 degrees. At the last, the filled substance is removed. Then, target form is fabricated by reversing a matrix structure.

If using this process, it can be reasonably expected that fabrication of a structure with difficult methods easily.

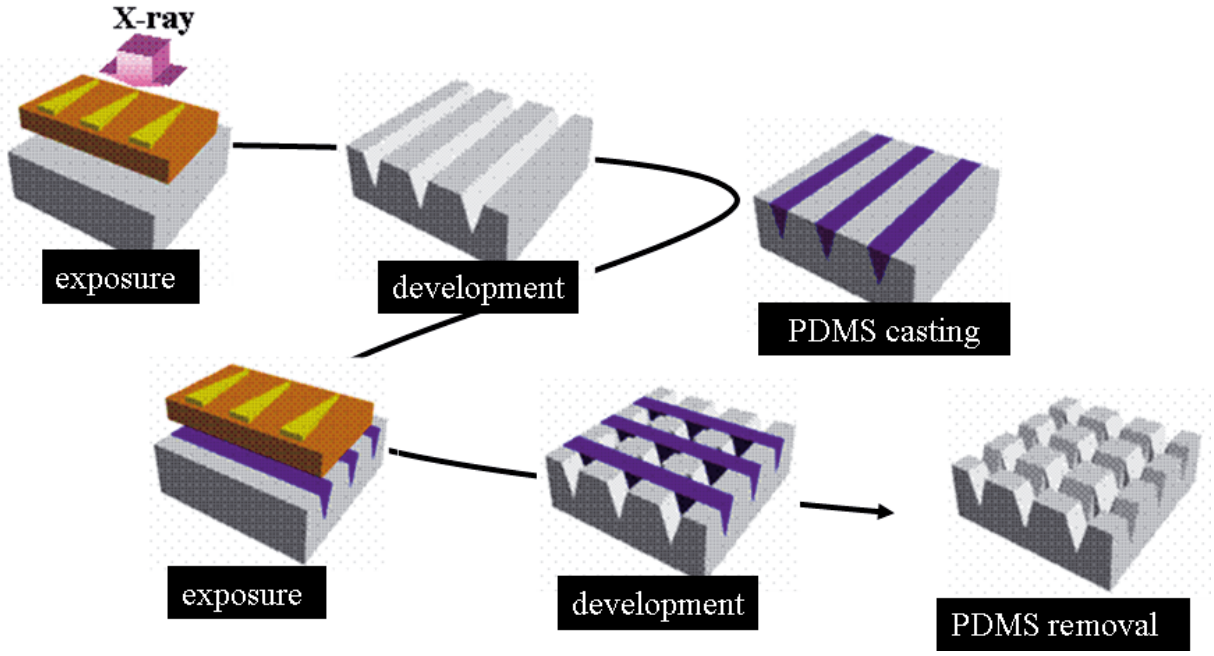

Fig.5 Process flow

2. Fabrication and Experimental Conditions

This time, it focuses attention on PDMS (Polydimethylsiloxane) as a material to fill. PDMS can be fabricated in a simple process, in addition molding and exfoliation have simply the advantage of being possible [7].PDMS blends base compound and hardener at a rate of 10:1.

A number of experiments were carried out using beam line number 13 (BL-13) 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 200μm 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. Polymethylmethacrylate (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 [8].

An X-ray mask consists of a Polyimide membrane with a thickness of 50 μm and an Au absorber with a thickness of 3.5 μm. X-ray mask used the thing of Optnics Precision Co.,ltd. Exposed PMMA structures gradually appear during development using a GG developer (60 vol% 2-(2-butoxy-ethoxy) ethanol, 20% tetra-hydro-1, 4-oxazine, 5 vol% 2-

amino-ethanol-1 and 15 vol% water). After that, stopper liquid (80 vol% 2-(2-butoxy-ethoxy) ethanol, and 20 vol% water) is used at the same temperature for 10 minutes, followed by DI-water rinsing for another 10 minutes.

3. Experimental Results

3.1 Characterization of PDMS

First of all, solubility characterization of PDMS is checked. SR light exposed to PDMS, and the PDMS is development by GG developer. Exposed area of PDMS is impossible to etch. PDMS is material which shows high chemical resistance. Therefore, PDMS is not etched by GG developer.

Next, absorption characterization of PDMS to SR is checked. Fig.6 shows process flow of this experiment. 20μm PDMS is casting on the PMMA sheet. After exposure, PDMS is removed, and developed PMMA process depth is checked. Fig.7 shows relationship of Dose and Depth which are both using PDMS and not using.

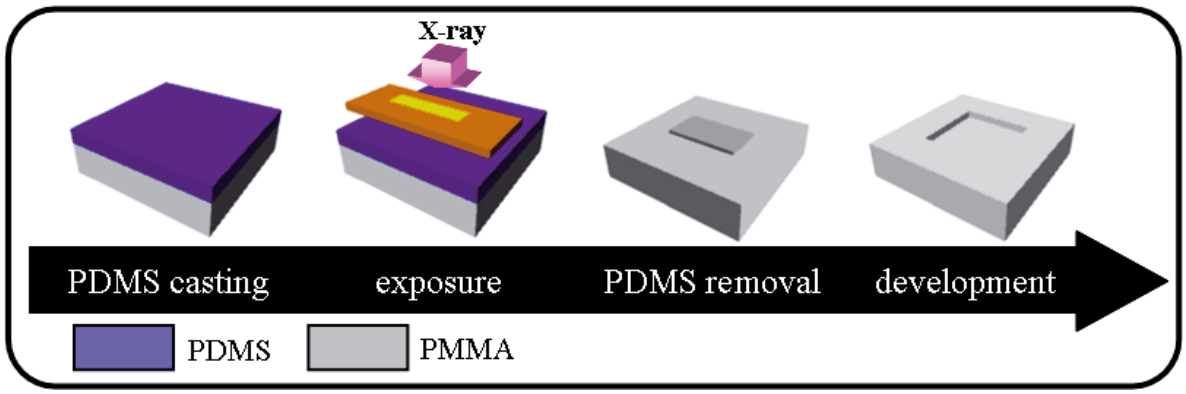

Fig.6 Research of absorption characterization of PDMS

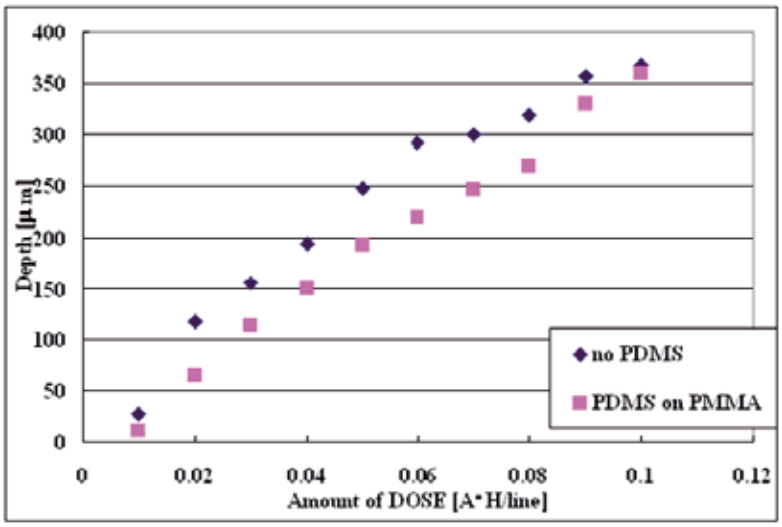

Fig.7 Dose-Depth

3.2 Fabrication of 3-D structure using new process

Fig.8 shows SEM photos which are completed 1st exposure and development. The dosage is 0.00677 A· h and development time is 3hour. Fig.9 shows SEM photos which is been casting PDMS. PDMS is baked 70 degrees C, and baking time is 2hour. Photograph of Fig.9 shows that filling was successful. Fig.10 shows SEM photos which are completed 2nd exposure and development. The dosage is 0.00677 A· h and development time is 3hour.

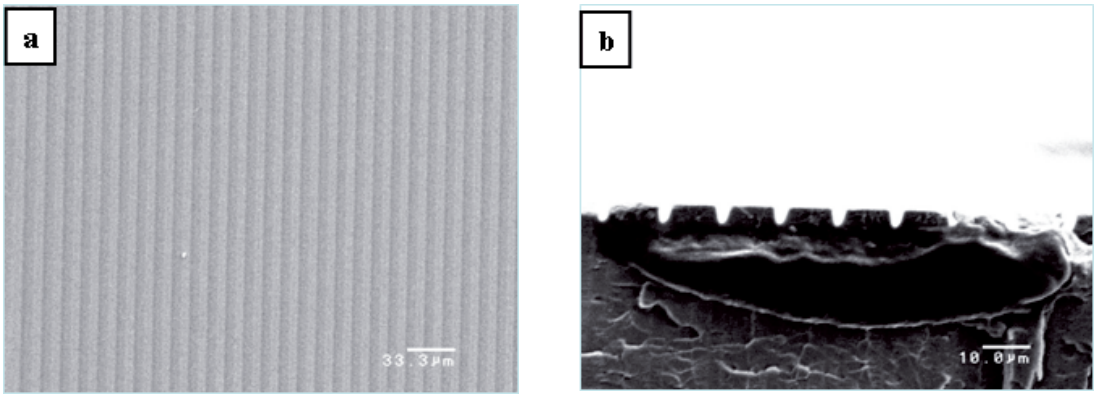

Fig.8 SEM photos of top view (a) cross-section view (b)

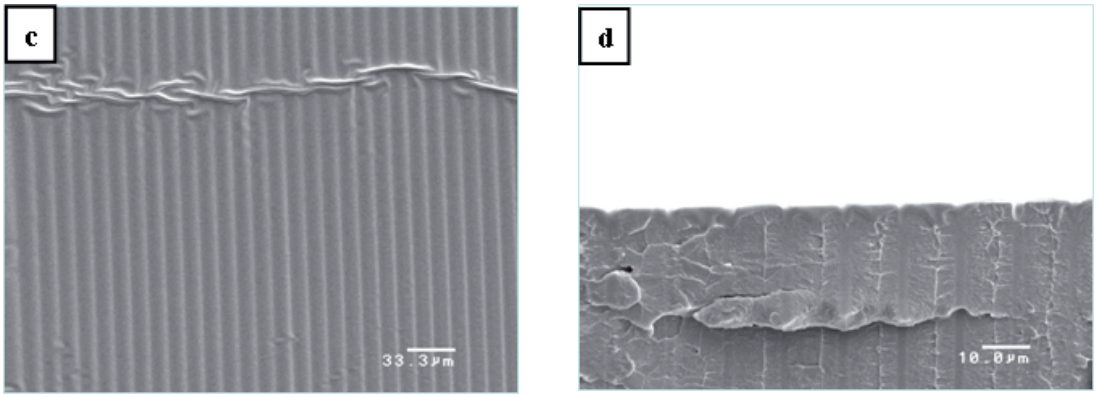

Fig.9 SEM photos of top view (c) cross-section view (d)

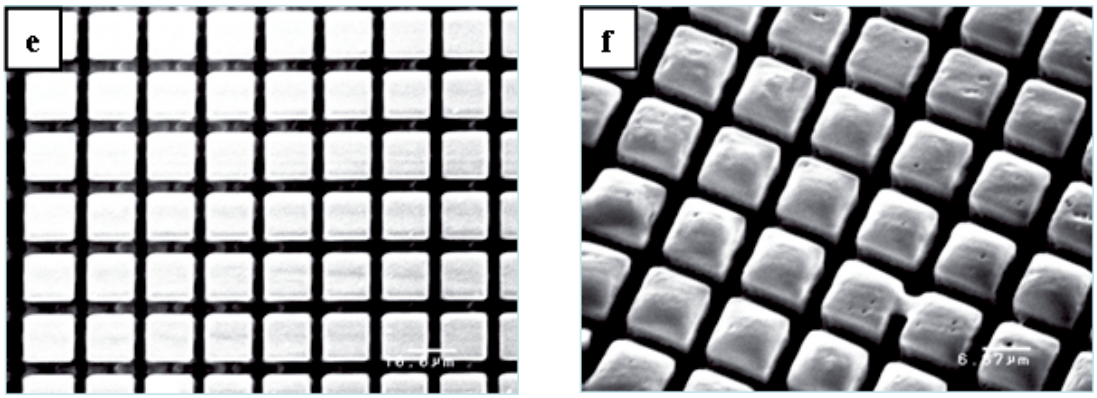

Fig.10 SEM photos of top view (a) cross-section view (b)

And, Fig.11 shows SEM photo of cross-section view at point where V-formation crosses. Photograph of Fig.11 shows that form of point where V-formation crosses was not successful. Reason of this result, absorbed energy which is during 1st exposure of PMMA is remained, therefore exposure energy of point where V-formation crosses is high and process depth became large. If transmission of PDMS make to be decreasing, fabrication of target form is possible. Therefore, the improvement plan which adds an additive to PDMS is required.

And, cross-section view of V-formation is not clearly. Reason of this result, it is thought that micro-loading effect influenced. Therefore, it is necessary that change of processing depth to line width is checked.

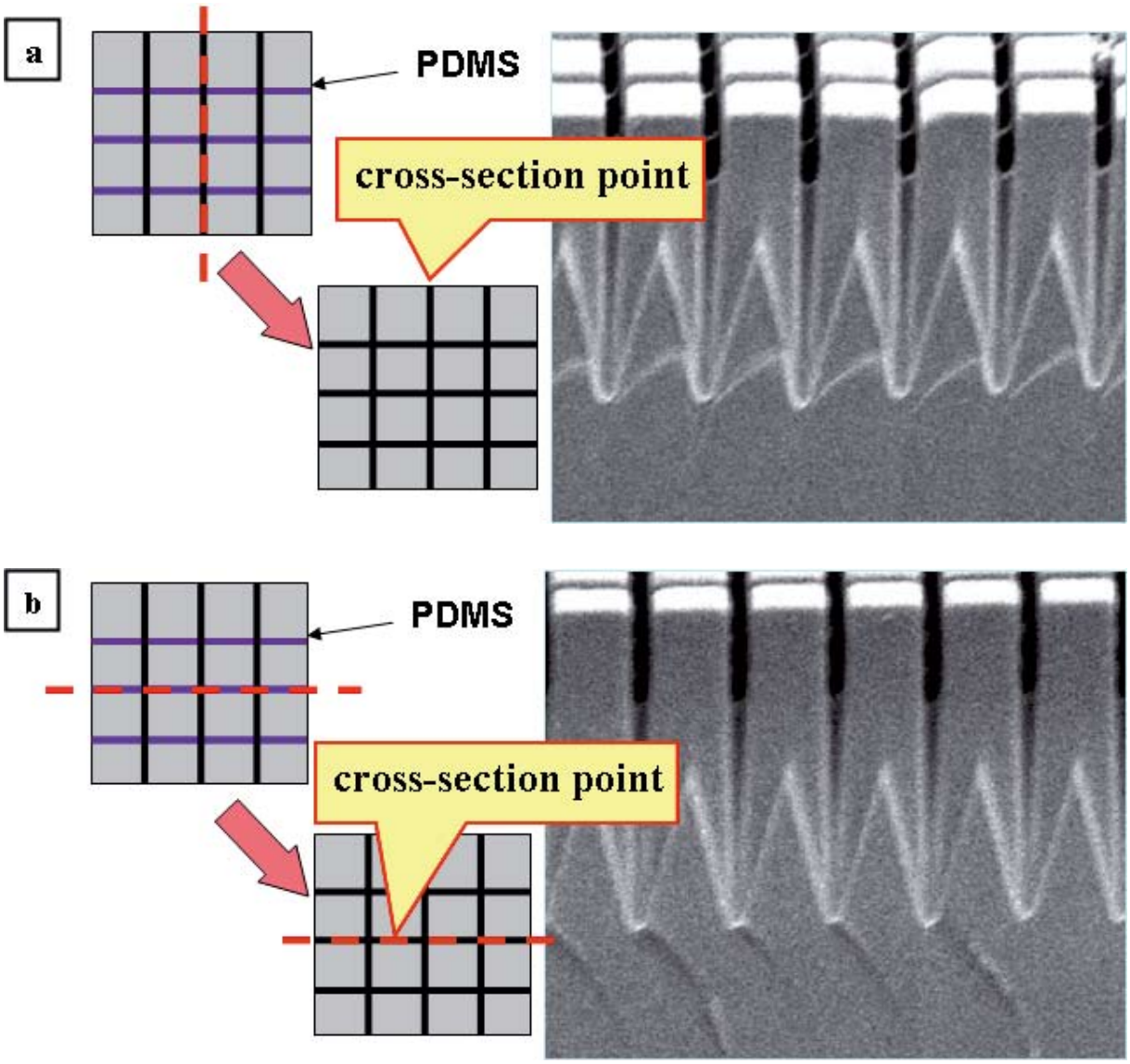

Fig.11 SEM photo of cross-section view

3.3 Influence by the micro-loading effect

In order to check change of the processing depth influenced by micro-loading effect, the processing depth to line width of 10μm, 15μm, 20μm and 25μm is checked about 0.05A·h and 0.03A·h. And, percentage of processing depth to processing depth of the domain where line width is wide is also checked. Results in case development time is 360min is shown in Fig.12. And similarly, results in case development time is 180min and 30min are shown in Fig.13 and Fig.14.

The results show that the processing depth becomes low as line width becomes small. As this reason, circulation of a developing solution gets so bad that the processing depth becomes deep to line width, therefore since the processing depth itself obtained is low when the amount of dosage is low, circulation of a developing solution is considered to have been good.

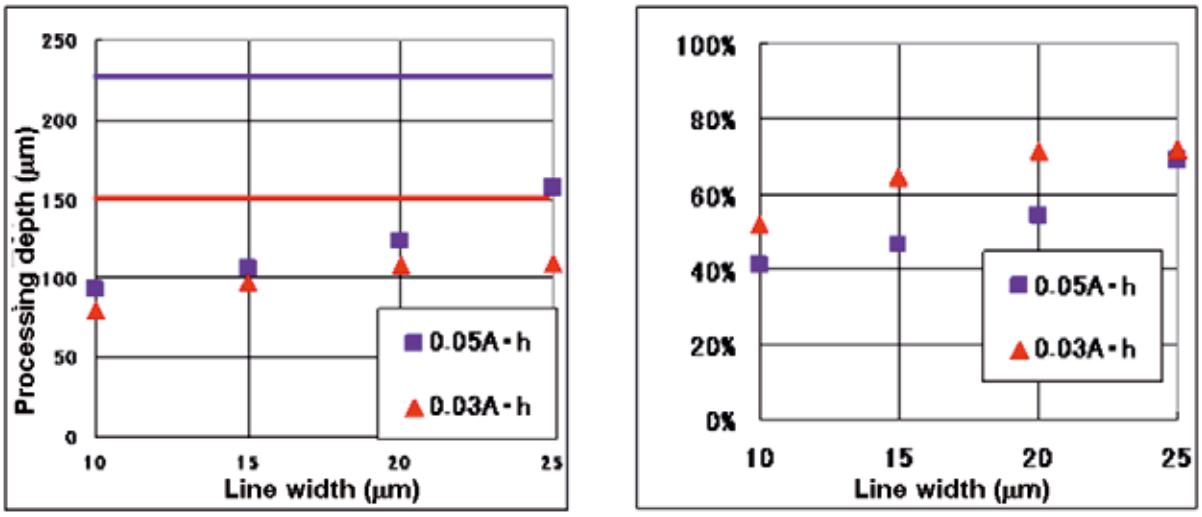

Fig.12 processing depth to various line widths (360min)

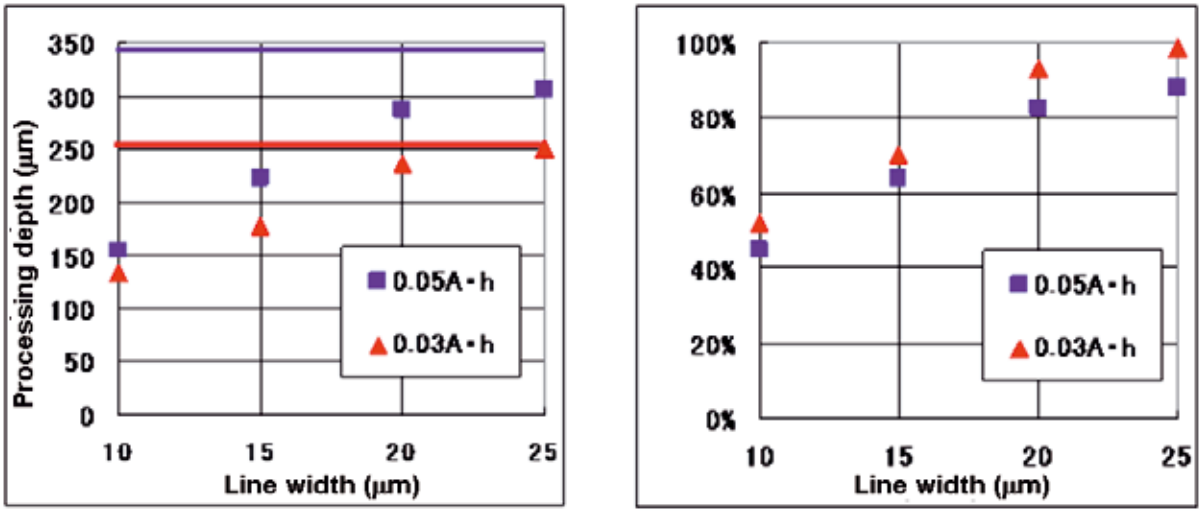

Fig.13 processing depth to various line widths (180min)

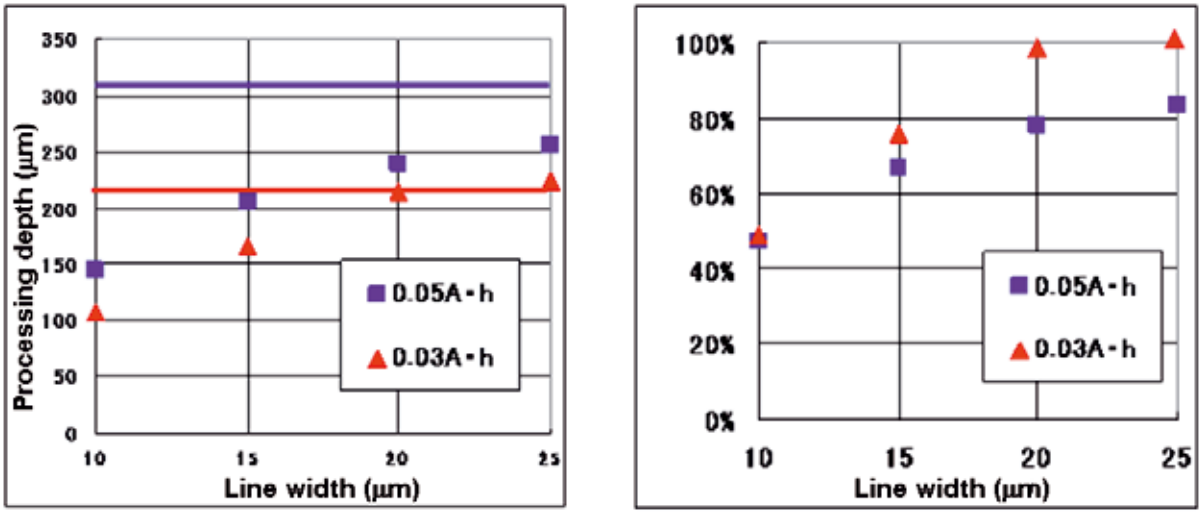

Fig.14 processing depth to various line widths (30min)

4. Conclusion

The newly process was devised. If using this process, it can be reasonably expected that fabrication of a structure with difficult methods easily. This time, it focuses attention on PDMS as a material to fill. PDMS can be fabricated in a simple process, in addition molding and exfoliation have simply the advantage of being possible. Characterization of PDMS is checked. The PDMS which is exposed by SR light is impossible developed by GG developer is checked. And, relationship of Dose and Depth which are both using PDMS and not using are checked.

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