A new process of the multiple X-ray lithograph technique

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1. Introduction

In the lithography technology, it is a very attractive challenge to fabricate a 3D structure. Generally, the multiple lithography technique is adopted for the purpose. The X-ray lithography has an advantage to etch a PMMA resist as deep as 300 μ m depth easily. When one wants to fabricate a 3D structured body, shown in Figure 1, a conventional process shown in Figure 2 has been adopted. This basic idea is to make the base structure first and then modify it by additional process.

Here, I propose a new process as shown schematically in Figure 3. This process contains a pre and main developments. In the pre-development process, it is controlled not to etch deeper than 30 μ m. This method has a benefit that the second exposure becomes easier than before, but it also has several problems, such as cracking and white deposit after the predevelopment. In this report, I discuss the new process in detail.

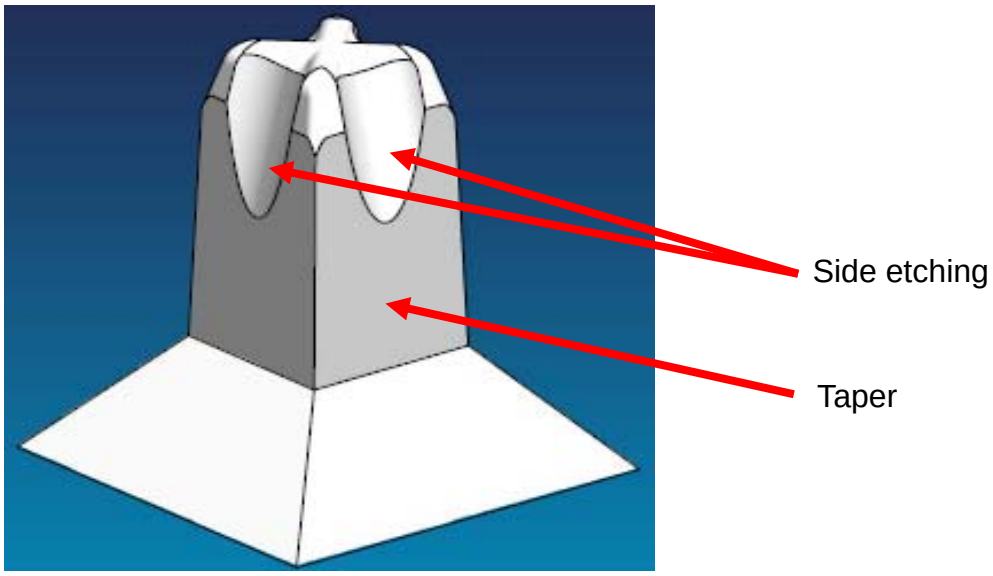

Fig.1. The 3D structure

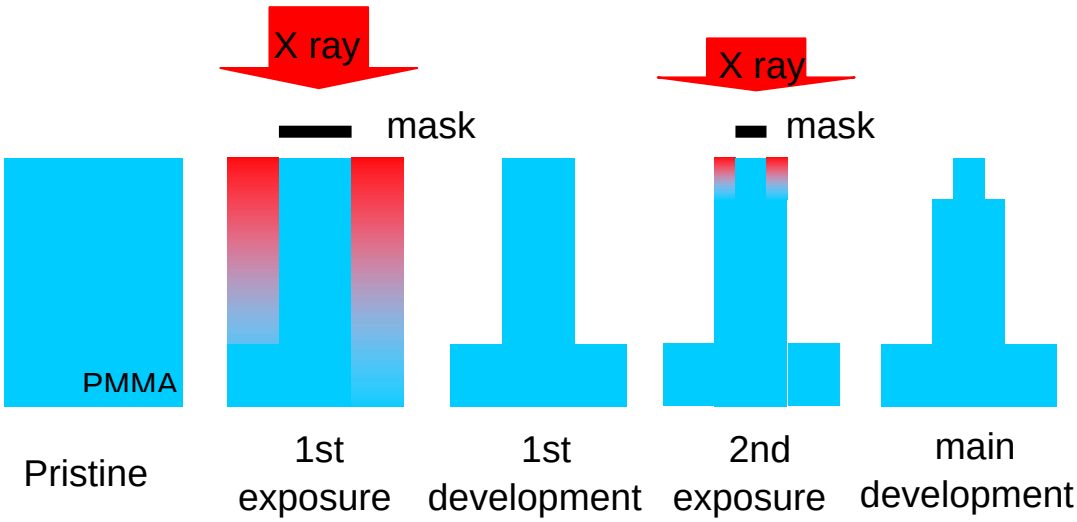

Figure 2. The conventional multiple lithograph process

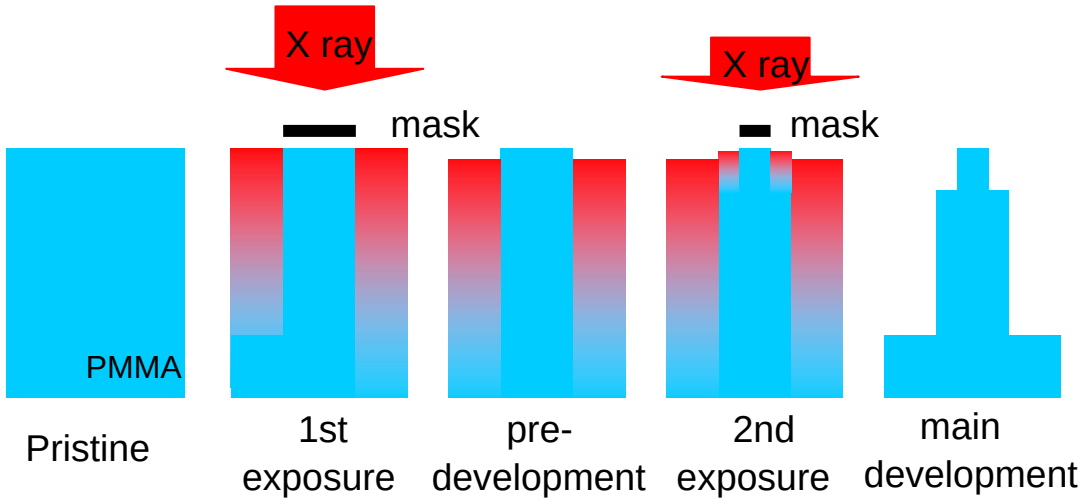

Figure 3. The proposed process in this paper

2. Results and Discussion

2.1 cracking

Cracking phenomenon is often observed in the case of high exposure, as shown in Figure 4. This is caused by the facts that an exposed PMMA resist shrinks and has an internal stress. Important point is that the cracks appear during and after development, but not before the development. This fact does not suggest that the cracks occur only by the shrinkage. To observe them carefully, the most of all occurred from the interface of non- and exposed area. It is thought that the starting point is necessary for the crack outbreak.

Actually with the exposure to require the depth of 300 (μm), there was no crack during the development. And it occurred during one week's safekeeping at room, and was thought by

drying of the PMMA.

To try the many methods, accidentally I found the effectiveness of annealing just after pre-development. The adequate temperature was 90 (℃), and no crack was done during more than one month's safekeeping. So we adopted the annealing just after the pre-development however the clear mechanism was unknown. The complicated mechanism to include the stress relaxation should be considered.

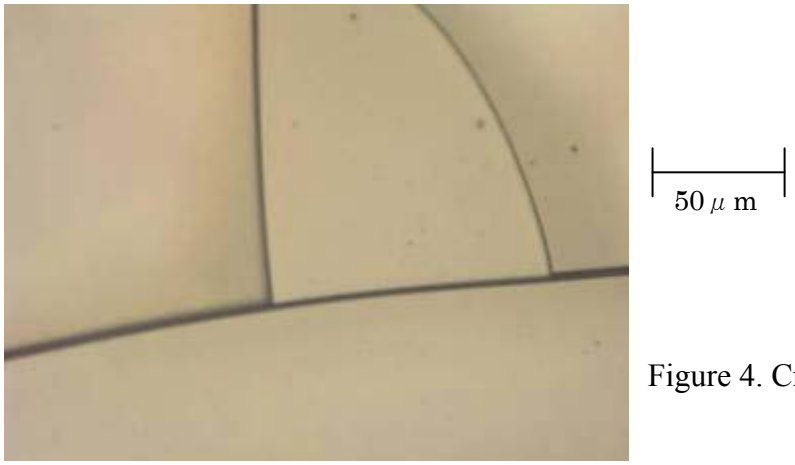

Figure 4. Cracks after development

2. 2. White deposits

After short time development less than 30 (min), white deposits were observed, as shown in Figure 5. But it disappeared after 60 (min). The white deposits were on the PMMA resist and could not be solved in water, but were easily scraped. These deposits should be a serious problem at the second process, since they obstruct the mask to irradiate the resist.

The early development of the PMMA was investigated in detail. I found a paste-like material formed on the resist. It was dissolved in a solvent, but after drying, was changed non-dissolved. Then, I wiped the paste-like material before drying.

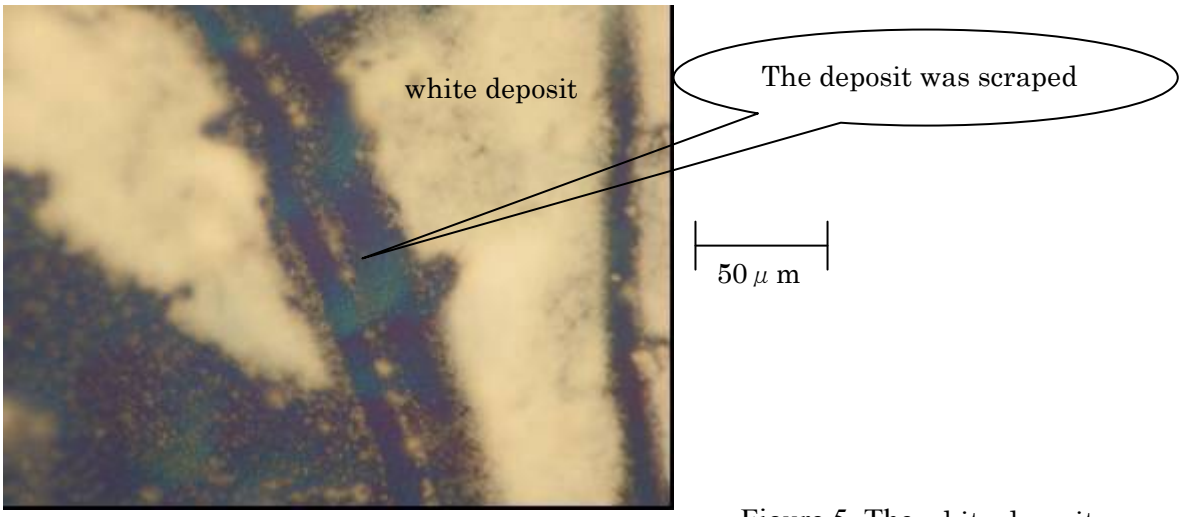

Figure 5. The white deposit

2.3. Depth of the development

The development temperature is used to be 38 (℃) in our laboratory. But in the pre-development, about 30 (μ m) deep etching was expected at high dose. Then, 20 (℃) was adopted as the pre-development temperature. A new calibration curve for 20 (℃) was necessary.

Figure 6 shows the etching depth dependence on the development time. From this curve, the pre-development time was determined to be 10 (min).

Figure 7 shows the whole resist photograph after the pre-development. The yellowed part is the exposed area. There was no white deposit and no crack after holding for 1 mouth at room at all.

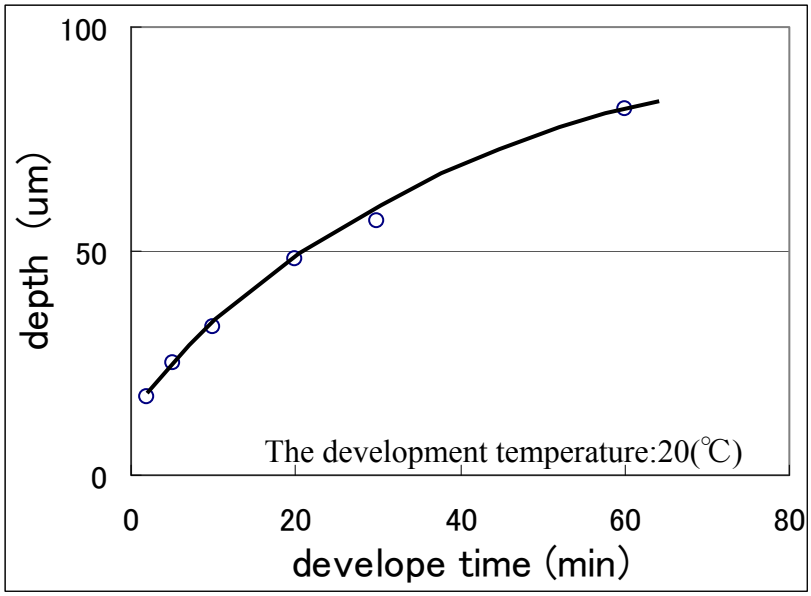

Figure 6. The depth change by development time

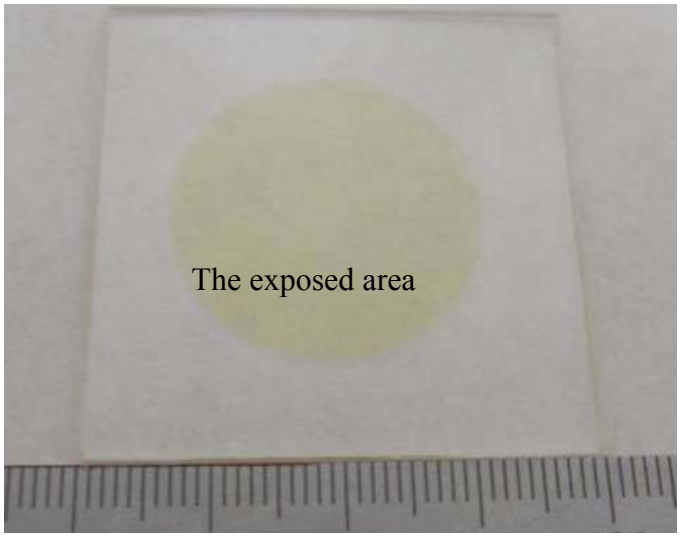

Figure 7. The whole photograph after pre-development

2.4. The final shape

Based on the examinations mentioned above, a series of the processes was carried out. At the 1st exposure, the 90 (μ m□ base was made. The mask used at the 2nd exposure is shown in Fig. 8. And the 2nd exposure, the "×" shape was overlapped on the base. It consists of a gold structure on polyimide thin film. The final shape after the main development is shown in Fig. 9.

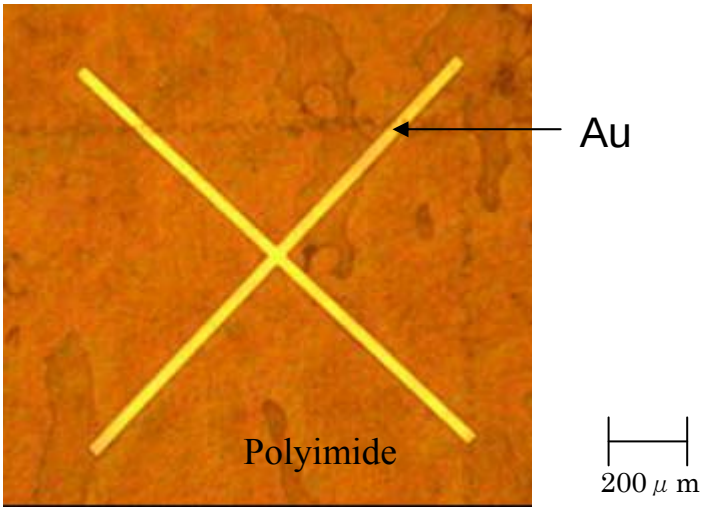

Figure 8. The X-ray mask at the 2nd exposure

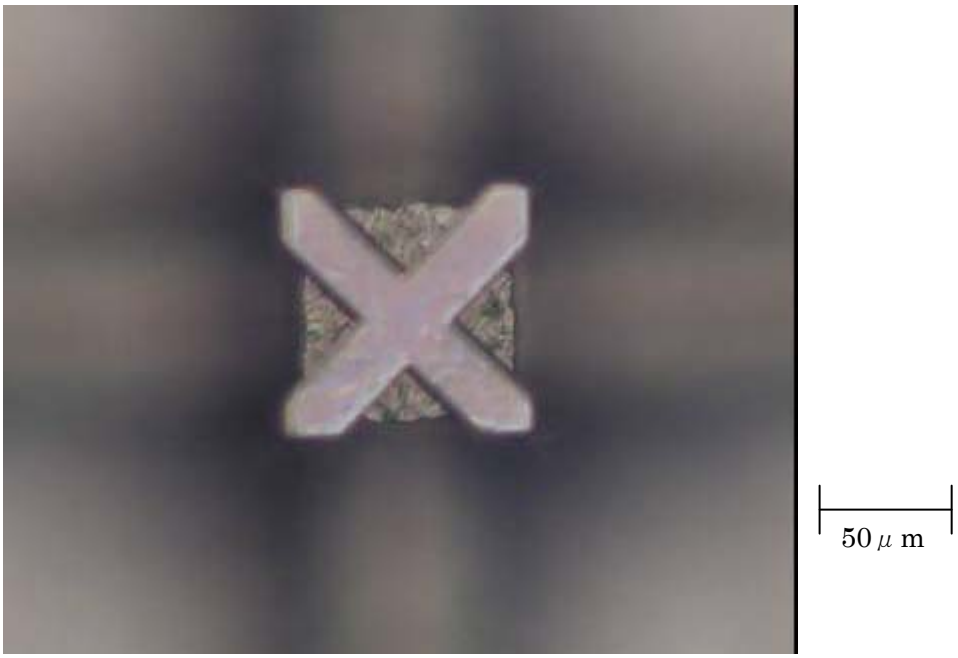

Figure 9. The final shape made by the proposed process

Summary

I proposed a new method of the multi lithograph process. The benefit of this method is that the 2nd exposure becomes easily when one adjusts the PMMA resist to the mask marker. But the cracks and the white deposits generation were seen after pre-development and holding. The two problems were overcome, and the process was established. But I do not know clearly why the cracks were prevented by 90 (℃) annealing. It is unlikely that the internal stress is reduced at this temperature. The different mechanism should be considered.