# High resolution hole patterning with EB lithography for NIL template production

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**Abstract**

Nano imprint lithography (NIL) is one to one lithography and contact transfer technique using template. Therefore, the lithography performance depends greatly on the quality of the template pattern.

In this study, we investigated the resolution and the defect level for hole patterning using chemical amplified resists (CAR) and VSB type EB writer, EBM9000. To form smaller pattern with high quality, high resolution resist process and high sensitivity etching process are needed. After these elements were optimized, we succeeded to form 24 nm dense hole pattern on template. In general, it is difficult to suppress the defect density in a large area because of fogging effect and process loading and so forth. However, from the view point of defect quality, 26 nm hole pattern is achieved to form with practical level in a large area. Therefore, we indicate the capability of forming 26 nm hole master template which will be required in 2019 from ITRS2013. These results show that this process is possible to obtain less than 30 nm hole pattern without enormous writing time.

As future work, we will imprint master to replica template and check the printability.

## 1. Introduction

### 1-1. Nano imprint lithography (NIL)

NIL is one of next generation lithography techniques replacing conventional photolithography.

Figure 1-1 shows NIL process flow. A master template is fabricated by EB lithography. After that, a lot of templates are replicated from the master template. Finally, these replicated templates are used on wafer patterning.

According to NIL development roadmap, currently the development of the finer pattern is conducted with NIL combined Self Aligned Double Patterning (SADP). Moreover, in order to cut process cost, NIL single process which means unmagnified transfer is being developed. In line & space (LS) template, the study of 1x nm was already reported in our previous study [1]. On the other hand, there is a hole template using for hole NIL as a new application.

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Mask Technology, edited by Nobuyuki Yoshioka, Proc. of SPIE Vol. 9984, 99840T

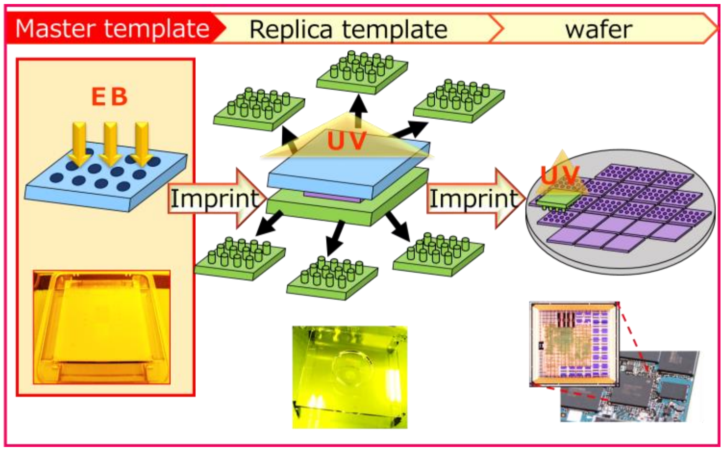


Figure 1-1 NIL process flow

**1-2. Significance of NIL for hole template**

In this section, we explain about significance of NIL for hole template. In EUVL, considering high throughput, photon counts decrease. Therefore, shot noise has effect on the formulating quality as shown in figure 1-2(a). The equation of variability is described in Kim's paper[2]. On the other hand, NIL is a direct transfer. Consequently, there is no shot noise on wafer patterning. Therefore, uniform hole patterns are fabricated as shown in figure 1-2(b). However, the pattern quality on wafer is decided by templates. So it is important to improve the quality of master template. Then, the performance of master template is a key factor.

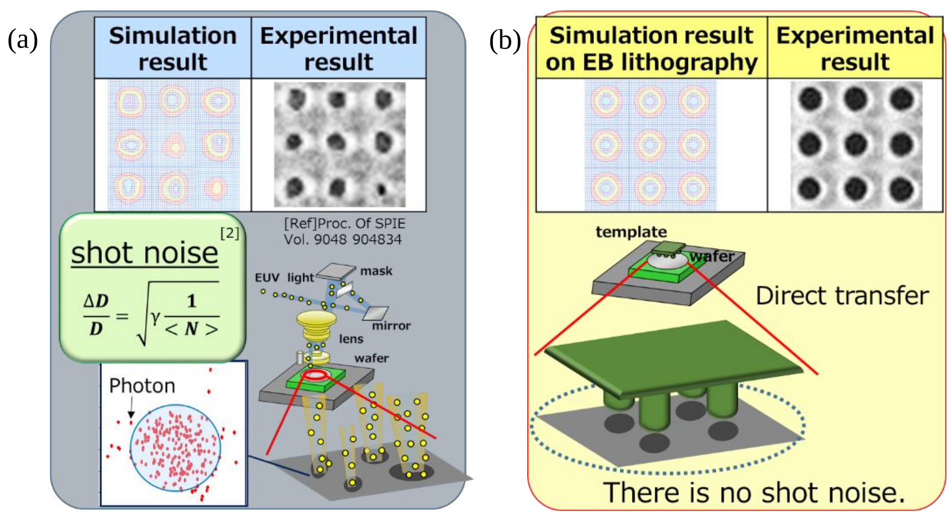


Figure 1-2 SEM images of each holes (a) EUVL[3] (b) NIL

**1-3. Necessary sensitivity towards our target**

According to ITRS 2013, the requirement size in this year is 3x nm but 2x nm is coming soon. And accordingly, shot counts are increasing. At this time, the concerned problem is write time. And we thought that target of write time is within 24 hours from the view point of the productivity. The necessary sensitivity is calculated by the relationship between shot counts and write time. As a result, 100 to 160 μC/cm² was calculated as a necessary sensitivity forming 2x nm hole template. This value is possible to achieve our target of write time. If we want to write 2x nm hole template within 24 hours, we have to use the resist with this sensitivity.

However, we already have the resist which is achieved to this throughput in LS template. Actually, in our previous work [1], the evaluation of LS pattern is conducted using resist which has the sensitivity of 140μC/cm². As a result, this LS pattern is succeeded to form hp 16nm. Therefore, we investigate the resolution of hole pattern on master template using this resist with high throughput and high sensitivity.

## 2. Experimental procedure

In this study, we used Qz substrate. Resist is positive-tone chemical amplified resist and the middle film is conductive hard mask, the bottom film is Qz. It is expected to write one master template included finer pattern within 24 hours as described in previous slide. With regard to fabricate pattern, we used standard mask production process which includes EB writing, PEB (post exposure bake), developing and etching as shown in figure 2-1.

We will describe the performance of hole pattern on master template using this process from next section.

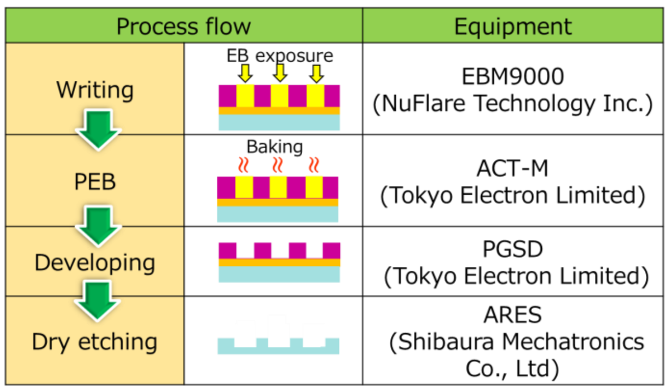


Figure 2-1 Process flow fabricating pattern

## 3. Results and discussion

### 3-1. Resolution of hole pattern at current condition

Figure 3-1 shows the result of evaluation under current process. These SEM images are shown resist pattern and after dry etching patterns. We can observe that hole of resist pattern is formed completely, but some patterns are not formed after dry etching. Actually, hole pattern cannot be formed below 30 nm under the conventional process. Then we discuss how these defects are occurred in next subsection.

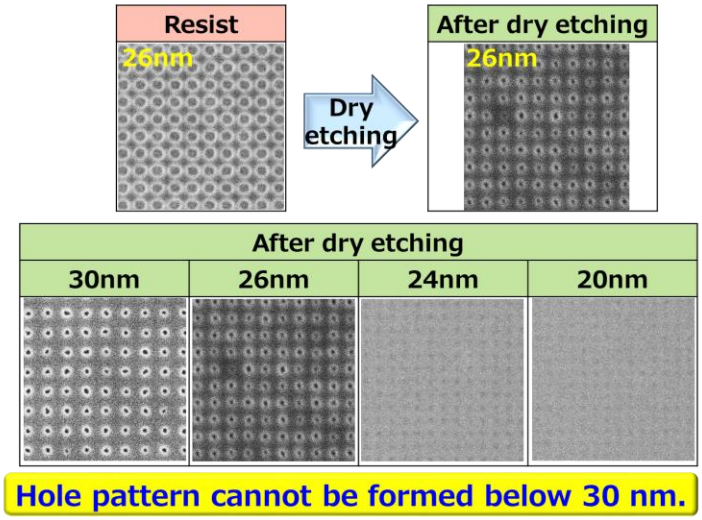


Figure 3-1 Patterns fabricated under this process

### 3-2. Mechanism of defects occurrence

Figure 3-2 shows mechanism of defects occurrence. At writing process, it is that beam profile contrast is getting worse because the beam resolution is insufficient. And at developing process, in some parts, there is a residue, so some patterns are not etched. However, if the developing time is getting long, a variation in the height and top roughness is occurred. So defects such as connected each holes are occurred at dry etching process. These mean that the etching sensitivity is not enough. Therefore, we added a new assist process for improving the etching selectivity.

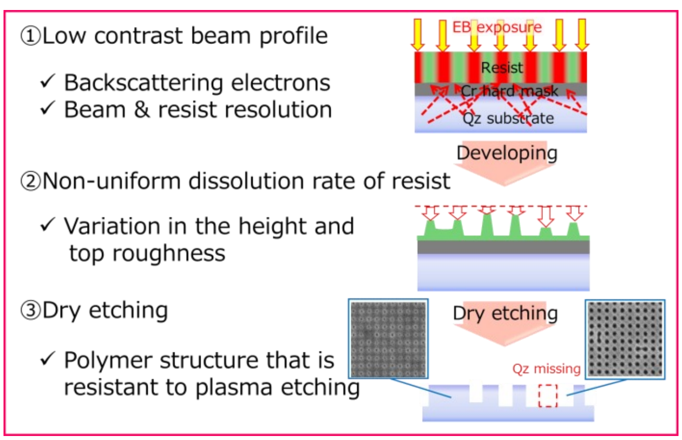


Figure 3-2 Mechanism of defects occurrence

### 3-3. Effect of assist process

Assist process is added between developing and dry etching process. This concept was increasing dry etching resistance in resist pattern. Figure 3-3 shows the SEM images at conventional process and with assist process after dry etching.

Hole pattern with assist process is succeeded to form without these defects. Therefore, it is found that new assist process is effective in improving the resistance against dry etching.

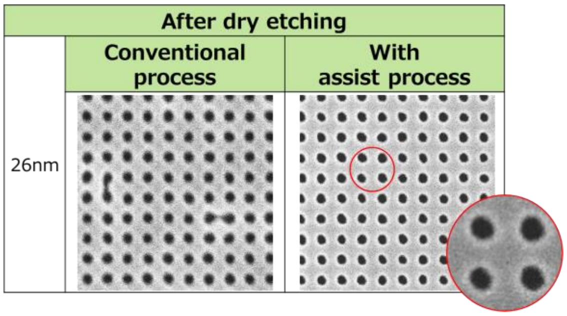


Figure 3-3 SEM images (a) conventional process (b) with assist process

**3-4. Resolution of hole pattern with assist process**

Figure 3-4 shows the image of pattern and these SEM images showed the resolution of hole pattern with new process. In conventional process, hole pattern couldn't be formed below 30 nm. However, in new process the resolution is achieved at 24 nm in new process even the edge. Below 20 nm, there is still no margin so far. In the future, we will evaluate imprinting to replica template.

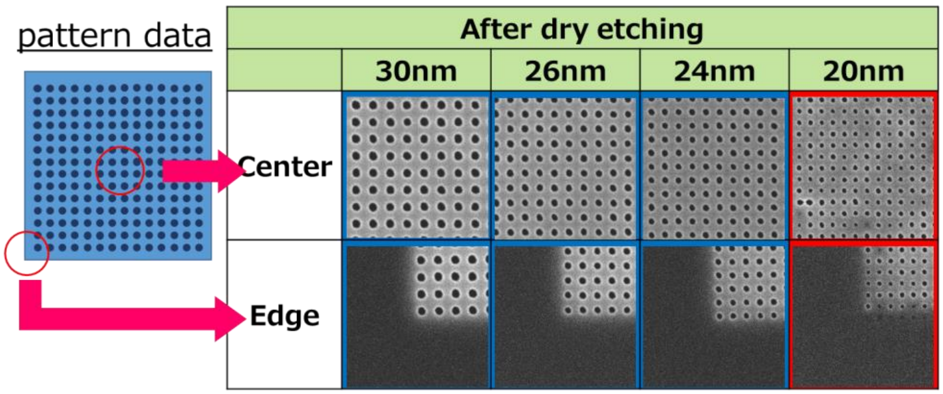


Figure 3-4 Each hole pattern under the condition with the long developing time and new assist process

**3-4. Results of defect inspection**

Finally, the defect inspection was conducted at the large area in 24 and 26 nm for ensuring quality. Each defect counts were 30.5ppb in 24 nm and 1.8ppb in 26 nm. In 24 nm, there is still some defects and in 26nm, it seems to achieve the defect free template soon. These defects are very tiny. Therefore, we can expect that it is capable of making defect free template. 2x nm template is coming to apply for hole NIL.

## 4. Summary

In this paper, we firstly reported to form hole template. This motivation was improving of fabricating process in master template used for hole NIL. We used the resist with suitable sensitivity which is possible to write within 24 hours and investigated the resolution and defects level of hole pattern on master template.

As a result, in hole NIL, defects counts in template were suppressed within excellent value. This key point was the innovation of resist process. So we can say that NIL lead hole lithography.

Finally, as a future work, we will evaluate hole pattern at full field and also imprint to replica template.

## References


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