Development status of back-end process for UV-NIL template fabrication

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ABSTRACT

Nano-imprint lithography (NIL) is eminently suitable for low cost patterning for nanostructures. As feature sizes of the UV-NIL templates are the same as the wafer patterns, there are enormous challenges such as writing and inspecting smaller patterns for NIL template fabrication. In our previous works, we achieved less than 16nm resolution with a 100keV spot beam writer and non CAR. We also reported optimization of metrology for NIL templates and the characterization of anti-sticking layers with scanning probe microscopies.

Normally the template is made from a 6025 photomask blank. After the blank undergoes a process similar to the photomask process, it is diced into 65 mm x 65 mm size and four pieces, and then each piece is polished into its final shape. Therefore it becomes difficult to inspect and clean them, because 65 mm substrates are unfamiliar in photomask industry. In order to reach the step for mass-production of the templates, the development of “back-end process”, which includes not only cleaning and inspection but also repair, dicing, polishing, and coating anti-sticking layers, is essential. Especially keeping low contamination level during dicing and polishing processes is one of the critical issues.

In this paper, we report our development status of “back-end process” for NIL templates. Especially, we focus on the techniques of reducing adder defects during dicing process and improving cleaning capability.

Keywords: template, back-end process, cleaning, dicing and polishing, protection layer

1. INTRODUCTION

UV nano-imprint lithography (UV-NIL) is one of the most promising techniques for low cost patterning of nano-structures. Therefore, it has the possibility to achieve the enormous progress in the field of not only semiconductors, but also optics, patterned media and bio-technology. However, as feature sizes of the UV-NIL templates are the same as the wafer patterns, there are enormous challenges such as writing and inspecting smaller patterns for NIL template fabrication. In our previous works, we have achieved less than hp 16nm resolution with a 100keV spot beam writer and non CAR processes [1]. We also reported optimization of metrology for NIL templates [2] and the characterization of anti-sticking layers with scaning probe microscopies [3].

Figure 1 shows a process flow for UV-NIL template fabrication. After a 6025 ptomask blank undergoes a process similar to the photomask process, it is diced into four smaller pieces, and then each piece is polished into its final shape according to specifications for imprint machines. In order to reach the step for mass-production of the templates, the development of “back-end process”, which includes mesa formation, dicing, polishing, cleaning, inspection, repair, and anti-sticking layers, is essential. In our previous work, we reported a good prospect to achieve the specifications of templates shape in suitable for NIL and method of accurate measurement of the shape [4].

As the dicing and polishing processes are added to typical photomask process, keeping low contamination level is one of the critical issues. So cleaning and protection techniques are key challenges because unique particles would attach on templates during dicing and polishing.

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In this paper, we report the development status of template quality after dicing and polishing. Especially we focus on optimization of layers protected from contaminations during dicing and polishing and also focus on new cleaning technique to remove strong-interacting particles.

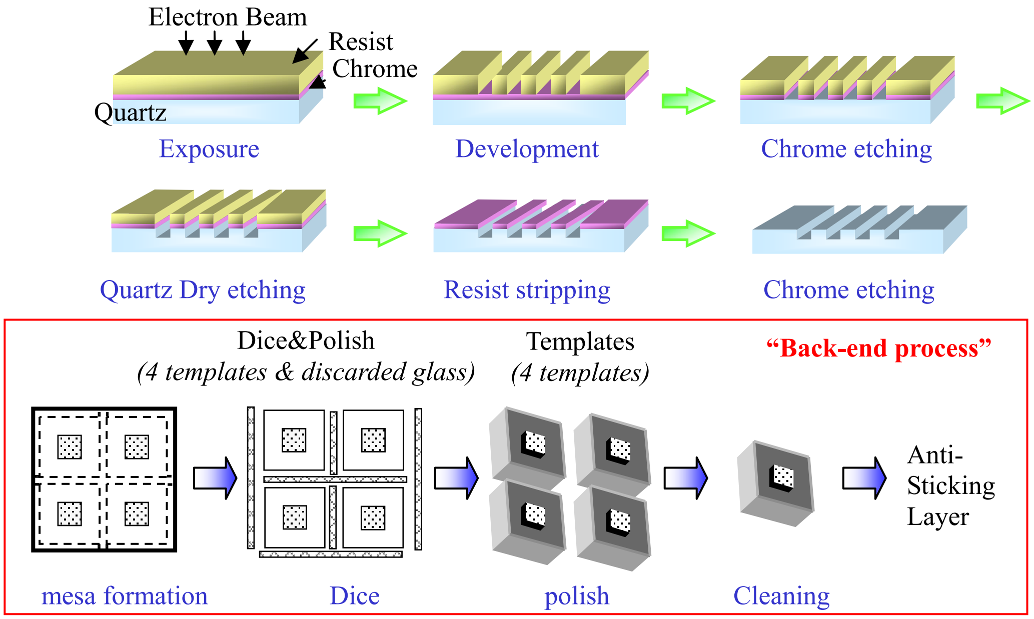


Fig.1: Process flow of UV-NIL template fabrication

2. EXPERIMENTAL

For the purpose of development of "back-end process", we prepared infrastructures of particle inspection tool and cleaning tool for 65mm templates and fabricated several 65mm templates diced from 6025 photomask. In order to improve quality of 65mm templates, protection layers, which prevent quartz surfaces from being attached by particles, are coated before dicing and polishing. After protection layer removal and cleaning, particle inspection is conducted. Fig.2 shows the procedure for particle inspection of 65mm templates. After cleaning for 65mm templates, we investigate residual particles with SEM and EDX (Energy Dispersive X-Ray Spectrometer). Table.1 shows the list of apparatus we used for this evaluation. Particles on quartz surface are detected down to 70nm with Magics.

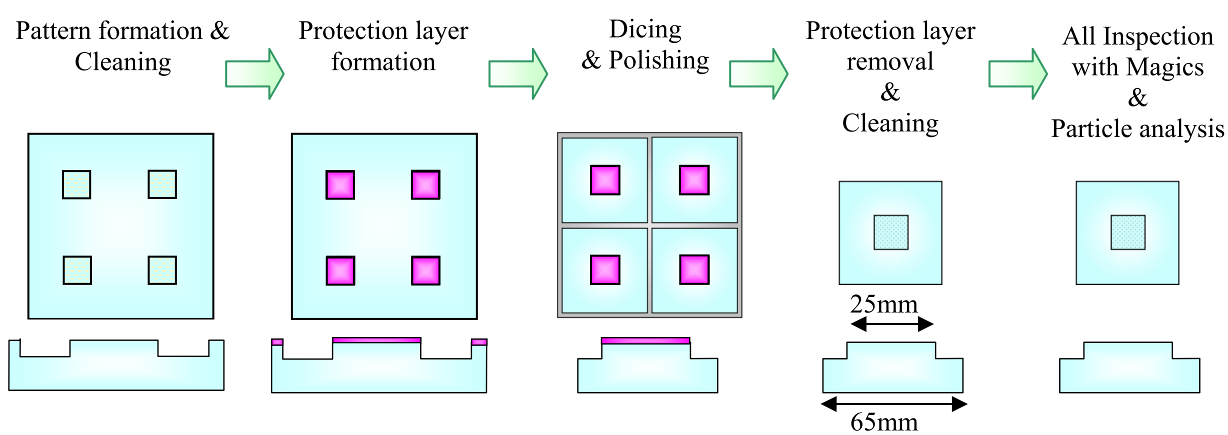


Fig.2: Procedure for particle inspection of 65mm templates

Table.1: Evaluation tool

65mm template Cleaning	Experimental tool at DNP (SPM + Surfactant + MS + Hot-DIW)
Particle inspection	Magics with a 65mm folder by Lasertec
Particle analysis	SEM (Ultra55 by Zeiss)
	EDX (QuanTax QX400 by Bruker)

3. RESULTS AND DISCUSSION

3.1 Development status of template quality

Firstly the number of residual particles on the 65mm templates without patterns after dicing, polishing and cleaning was detected with Magics. Fig.3 shows the history of particle reduction. Inspection area was 25mm x 25mm on the mesa surfaces. At the beginning of 65mm template fabrication, many particles were detected on 02/2007. In one and a half years, the number of particles becomes three digits smaller by optimizing protection layer, removal method, and cleaning.

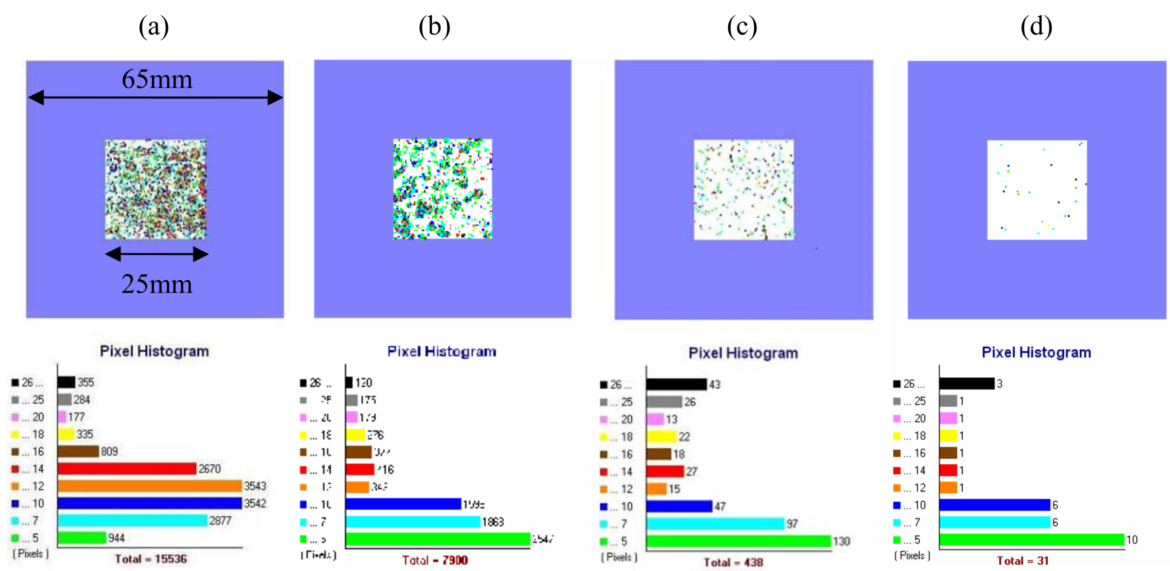


Fig.3: Particle inspection results on (a) 02/2007 (b) 05/2007 (c) 11/2007 (d) 07/2008

3.2 Particle inspection of templates with LS pattern

We fabricated templates with 1um line and space (LS) patterns overall on the mesa area, which were fabricated by same processes as shown in Fig.2. In addition, designed defects were added to LS pattern area for sensitivity analysis of inspection with Magics. Fig.4 shows four types of designed defects. Fig.5 shows a particle inspection result for the 65mm template with LS pattern after cleaning. Not only a few particles but designed defects are detected as shown in fig.5 and edge bump defects of 70nm can be detected with high inspection sensitivity mode as shown in Table.2.

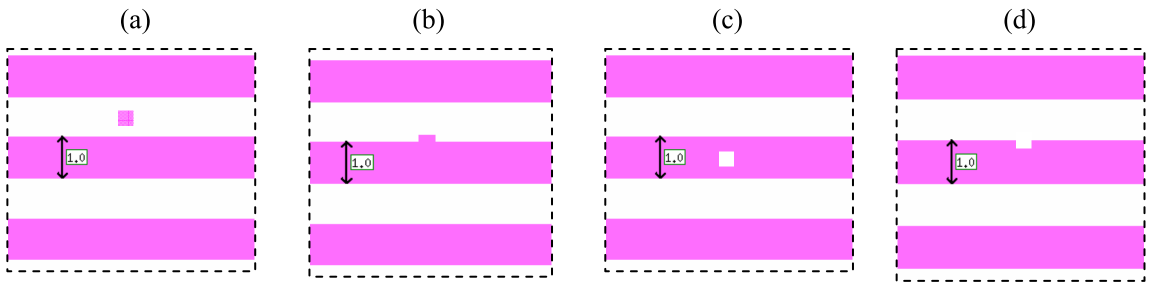
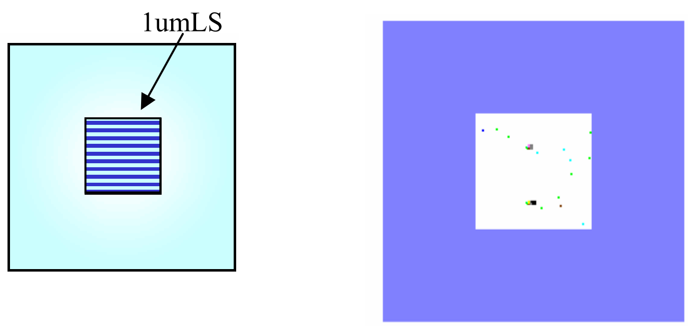


Fig.4: Defect types for sensitivity analysis of inspection for LS pattern;
(a) Iso Bump (b) Edge Bump (c) Iso Trench (d) Edge Trench



Total # of particles	**15**
Detected Designed defects	**103**

Fig.5: Particle inspection results for 65mm template with LS pattern, after cleaning

Table.2: Results of sensitivity analysis of inspection for LS pattern

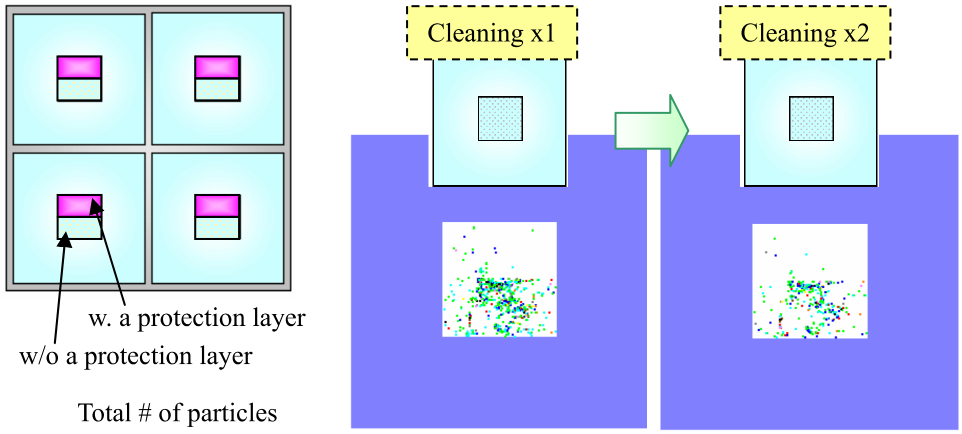
Defect size [nm] →

Defect Category														
Iso Bump	90	100	110	120	130	140	240	340	440	540	640	740	840	940
Iso Trench	50	60	70	80	90	100	200	300	400	500	600	700	800	900
Edge Bump	90	100	110	120	130	140	240	340	440	540	640	740	840	940
Edge Trench	50	60	70	80	90	100	200	300	400	500	600	700	800	900

Not detected
Detected with low sensitivity
Detected with High sensitivity
Not printed

3.3 Evaluation of adder particles with and without protection layers

In order to evaluate the effect of the protection layer, we prepared special templates covered with the protection layers on the half of mesa area. Fig.6 shows particle inspection results of the special templates. On the down side of mesa area without the protection layer, many particles were observed after cleaning or even after several times of cleaning. On the other hand, much less number of particles was observed after cleaning on the top side of mesa area with the protection layer.



Total # of particles

w. protection area	**41**	**9**
w/o protection area	**916**	**480**

Fig.6: Particle inspection results (a) after 1x cleaning (b) after 2x cleaning

3.4 Residual particle analysis after cleaning

We investigated some particles on the quartz surface via the process covered without protection layers by EDX tools. As shown in fig.7, both particle 1 and particle 2 seems to be SiO2 because their spectra are almost the same as that of the reference. In EDX condition, we set HV at 5kv that enable longitudinal resolution to be under 200nm. Particle 2 was found to be large enough to determine its components.

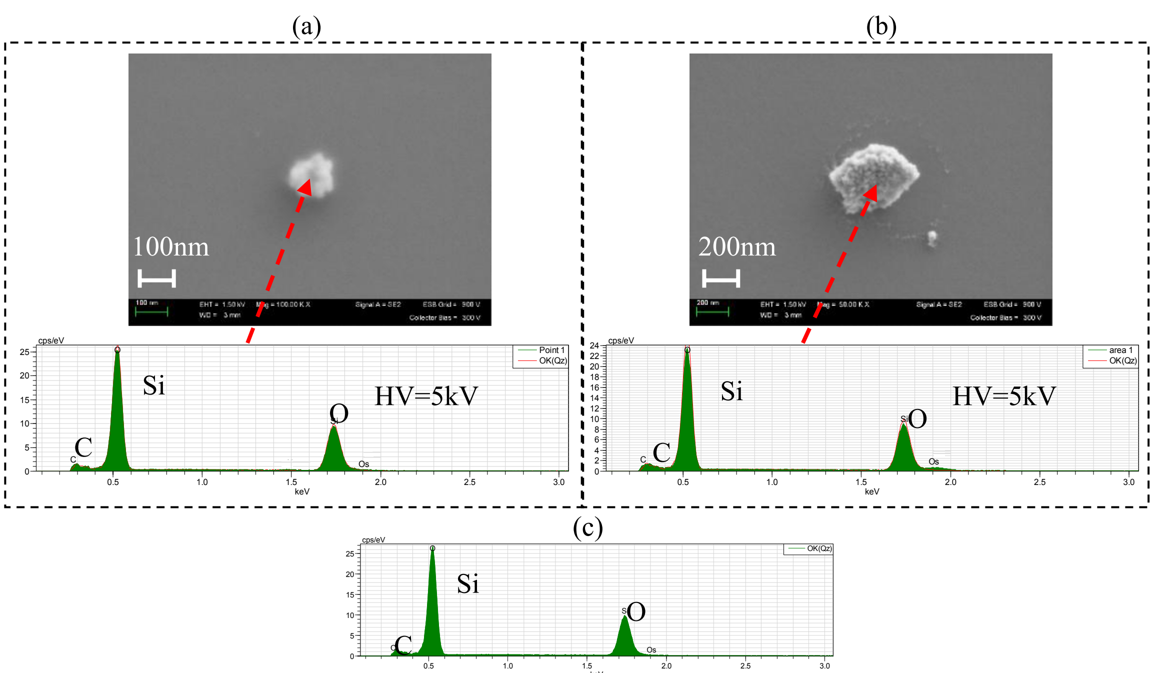


Fig.7: Results of particle analysis (a) particle 1 (b) particle 2 (c) reference (quartz)

3.5 Discussion: Effect of protection layers for dicing and polishing

In 3.4 sections, strong-interacting particles seem to be SiO_2 and to attach during dicing and polishing. So it is important to prevent them from attaching with quartz surfaces. Fig.8 shows the schematic description of the effect of protection layers. Particles on the protection layer can be removed along with the protection layer removal. However in this regard, it is very important to prevent SiO2 particles from reattaching during the protection layer removal or cleaning.

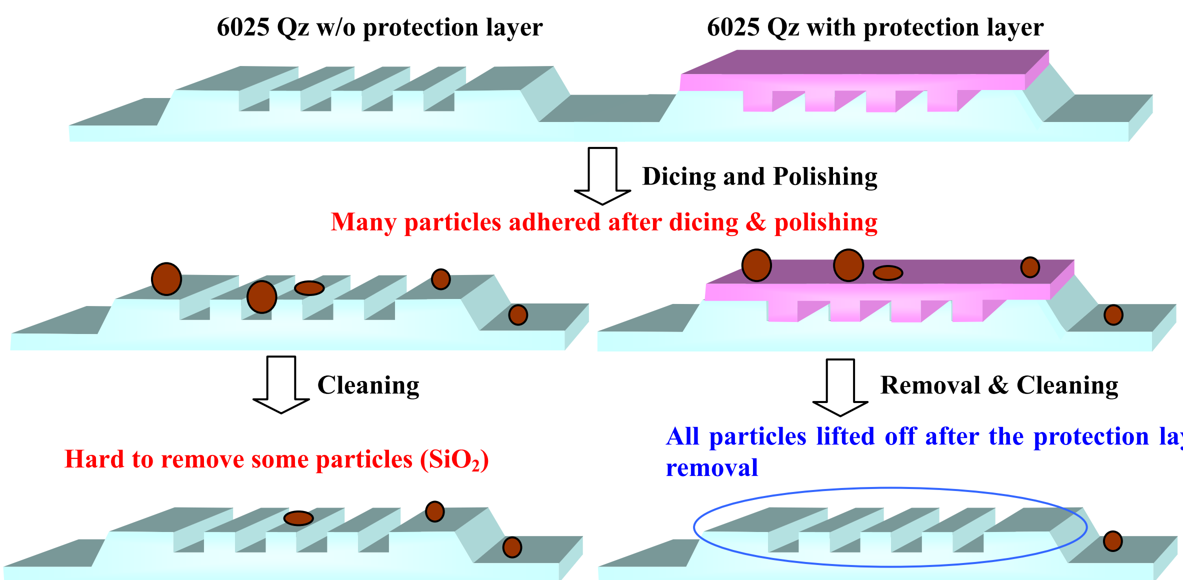


Fig.8: Description of the effect of layers protected from contamination during dicing and polishing

3.6 Performance of Hamatech MaskTrack® cleaner

We prepared four pieces of templates that were fabricated through different processes respectively. Condition A, B and C had protection layers during dicing and polishing. On the other hand, Condition D didn't have any protection layers. After dicing and polishing, we conducted three times of cleaning by experimental cleaner at DNP and one time by a new cleaner (Hamatech MaskTrack®). Fig.9 shows results of particle inspection after several times of cleaning. X axis of this graph whose scale is logarithmic is total number of particles. We found that it is possible to remove most of the particles on condition A, B and C (with protection layer) by the new cleaner, but hard to remove on condition D (without protection layer) even by the new cleaner. And also the new cleaner demonstrates much better performance than experimental cleaner.

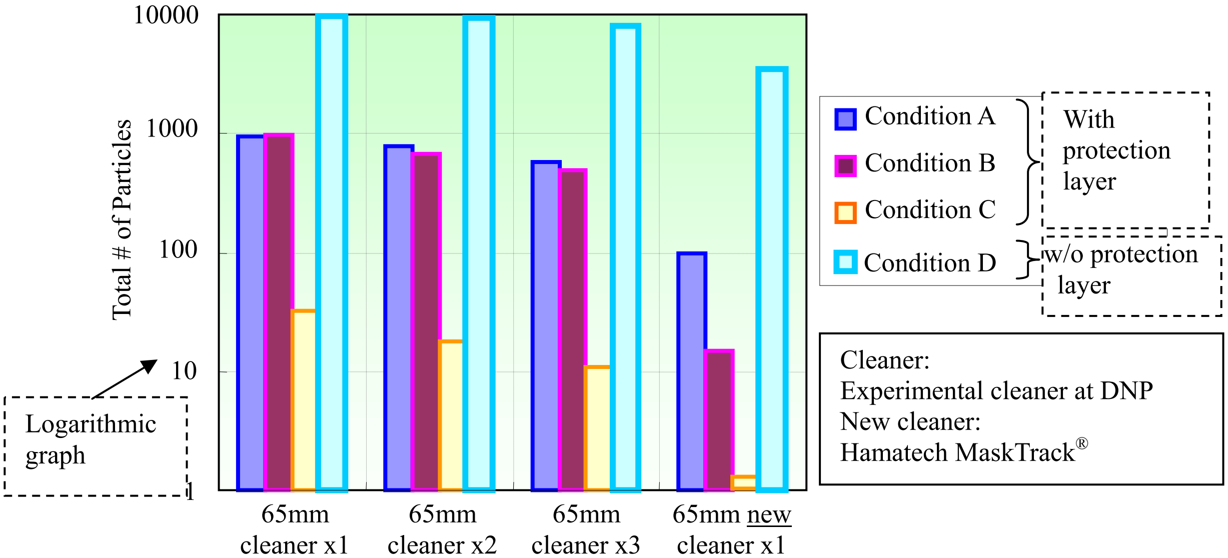


Fig.9: Total number of particles of four pieces of 65mm templates after dicing and polishing

4. SUMMARY

- We have improved quality of templates by optimizing layers protected from contaminations under dicing and polishing
- It is difficult to remove most of the particles without protection layers
- Main component of strongly-interacting particles with quartz surfaces seems to be SiO2 according to EDX analysis
- Hamatech MaskTrack® demonstrates much better performance than experimental cleaner
- To achieve templates with zero defects, it is important to prevent strongly-interacting particles from reattaching to quartz surfaces during protection layer removal or cleaning

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