CHAPTER 4 Measurement

This chapter presents the measurement of FIB mask and the microlens fabricated by FIB mask.

4-1 FIB mask measurement

In order to check the influence by the spot of the ion beam, a test pattern has been applied in the mask in addition to the lens pattern. The nine-level test pattern is shown in Figure 4-1. The whiter area of in pattern will be etched deeper than darker area. Figure 4-2 shows the measurement of the test pattern rotated counterclockwise by 90˚ by WYKO. The test pattern is blurred. So the data of the test pattern is changed to have a larger distance between two spots, such that each one spot can be recognized. One of the measurements is shown in Figure 4-3. The depths of nine test patterns are plotted in Figure 4-4, and the maximum depth is 160nm.

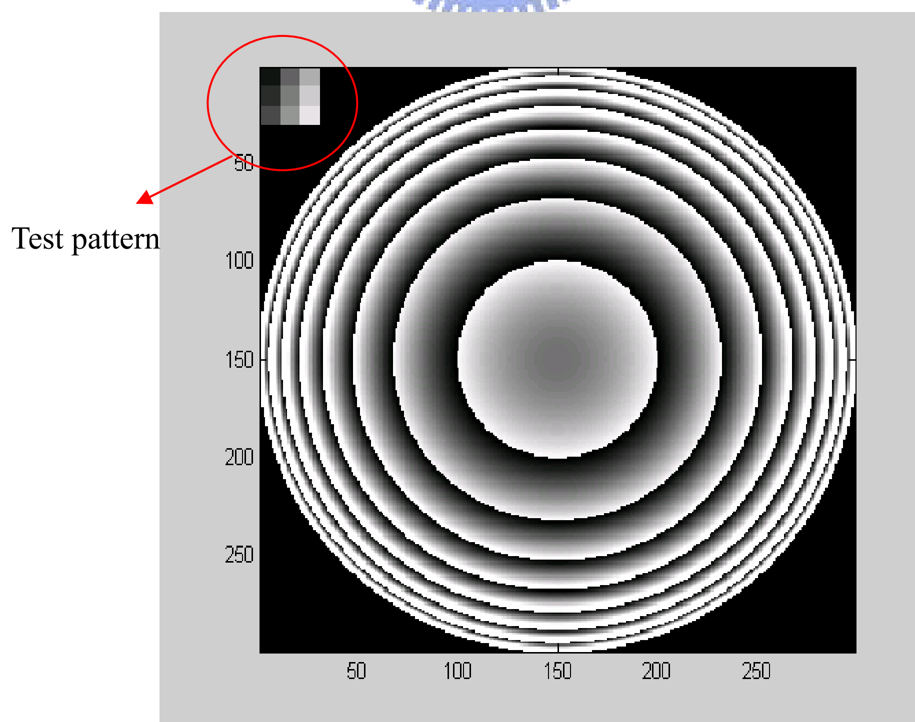


Figure 4-1: Pattern on the FIB mask.

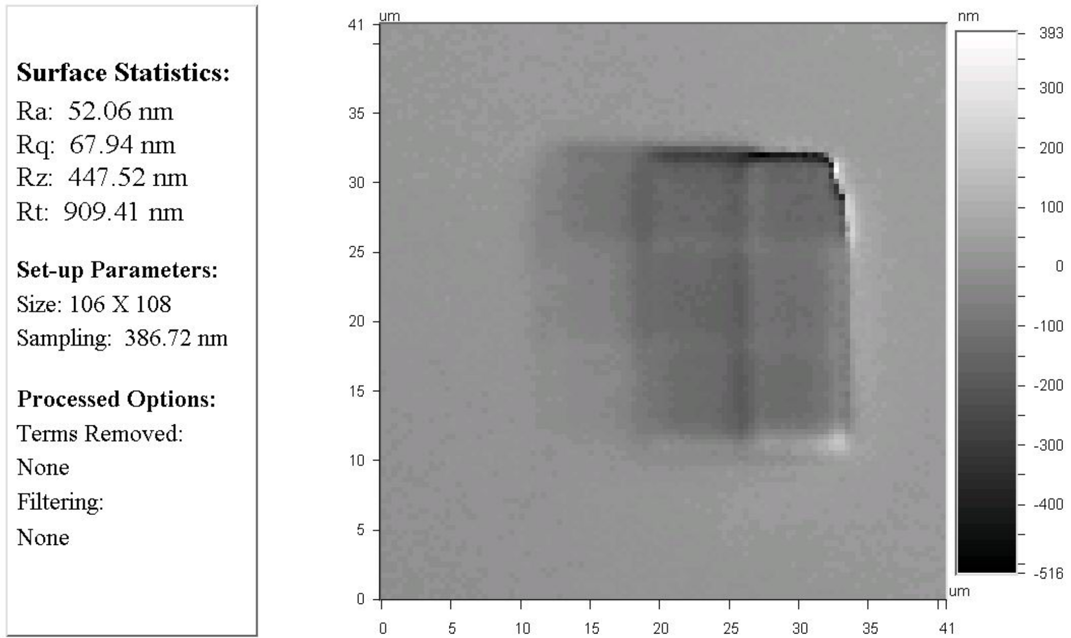
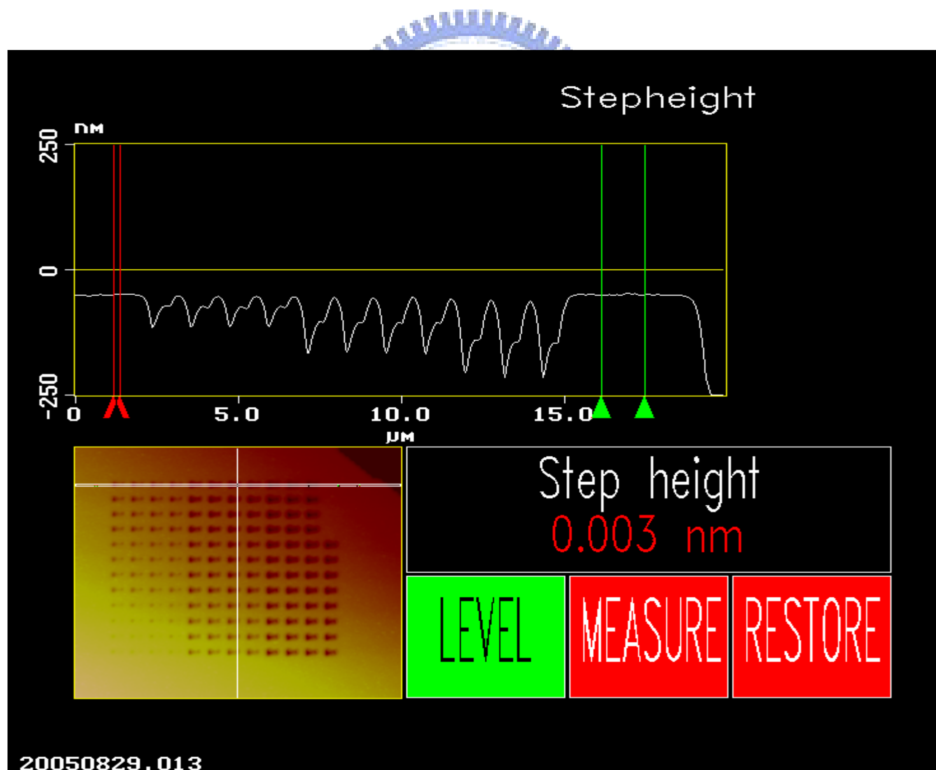
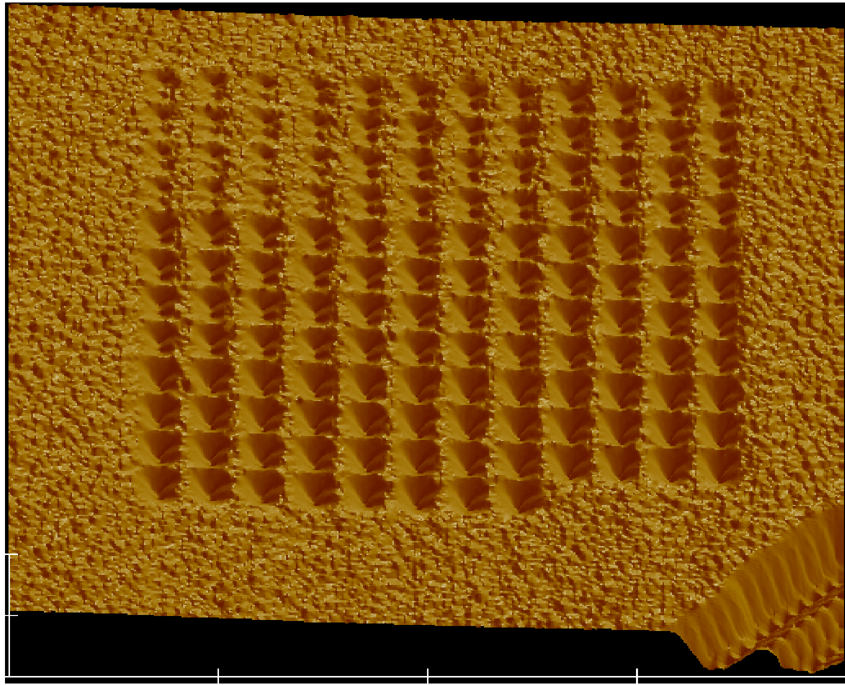


Figure 4-2: Etched test pattern measurement.

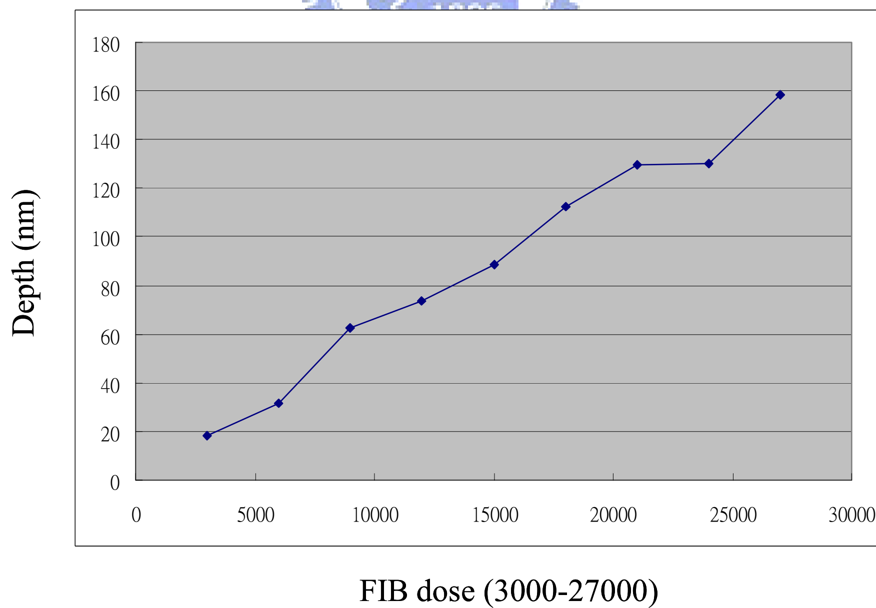


(a)



(b)

Figure 4-3: (a) Test pattern measurement by AFM. (b) 3D view with 180˚ rotation.



FIB dose (3000-27000)

Figure 4-4: Depth of the test pattern.

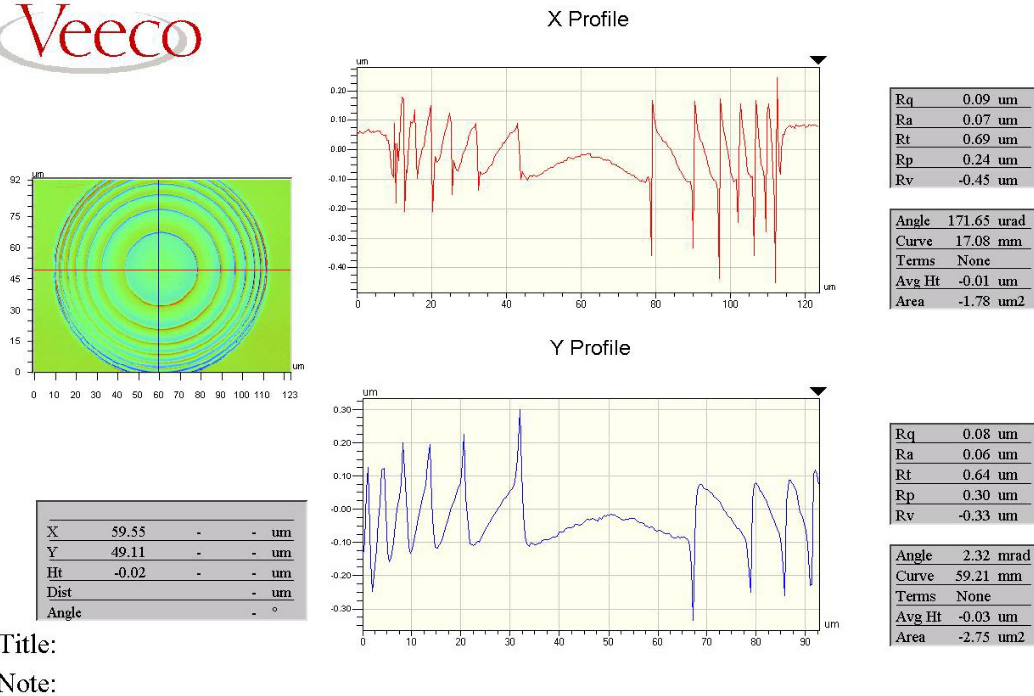


Figure 4-5: 2D profile measurement of Si_3N_4 by FIB milling.

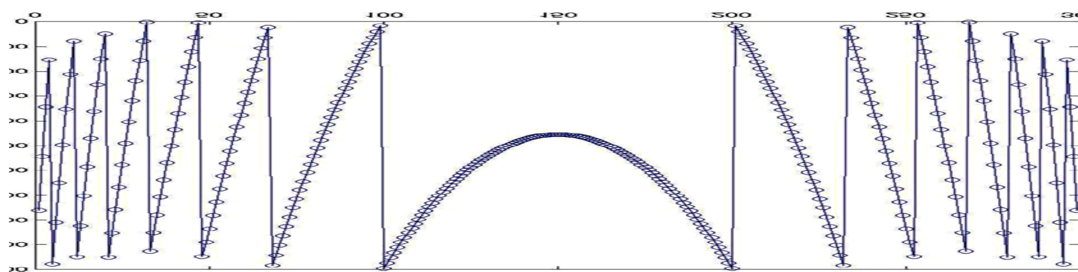
The measurements of FIB patterns by different instruments, is also compared. First, for the same pattern, the depth by WYKO is the twice the depth by AFM. Second, the two-dimensional measurements in both x and y direction by WYKO are asymmetric, as shown in Figure 4-5. The fringe scanning direction and the transparency of Si_3N_4 layer will cause interference effect. So for this kind of transparent material, AFM measurement will be better than WYKO.

During the FIB mask fabrication process, some phenomenons may cause the variation in the mask surface profile. If the mask profile is changed, the transmittance will be different, such that the microlens will have an undesired form. The ion beam current of FIB system was set to 1000pA with the uncontrollable variation of 100 to 200pA. The measurement of the mask profile is shown in Figure 4-6. The cross-section of designed pattern is shown in Figure 4-6 (a). The AFM measurement of the FIB etched pattern for 20 minutes is shown in Figure 4-6 (b). In the middle

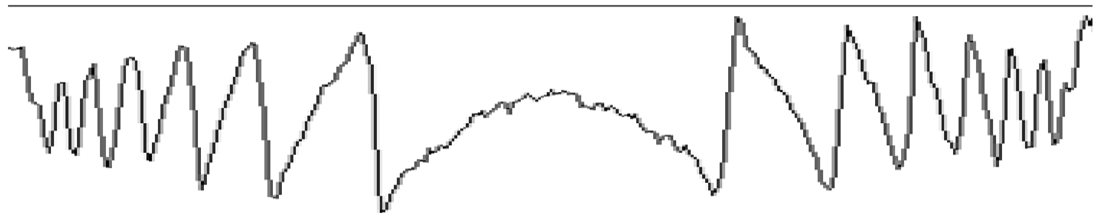
circle, the pattern profile is good; however, in the outer rings, the pattern is etched shallower than middle circle. That is the undesired result.

In order to solve the phenomenon, the compensation of the design data is done as shown in Figure 4-6 (c). Then, the AFM measurement of the FIB profile by the compensated data for the etch time of 30 minutes is shown in Figure 4-6 (d). The compensation seems useless in this measurement. To check the data precisely, the uncompensated data is applied again. Profile measurement for the etch time of 75 minutes is shown in Figure 4-6 (f). However, the depths of the outer rings are larger than the middle circle. That is unreasonable compared to Figure 4-6 (b) with the same applied data. Maybe the reason is the FIB system unstable in supplying electric current.

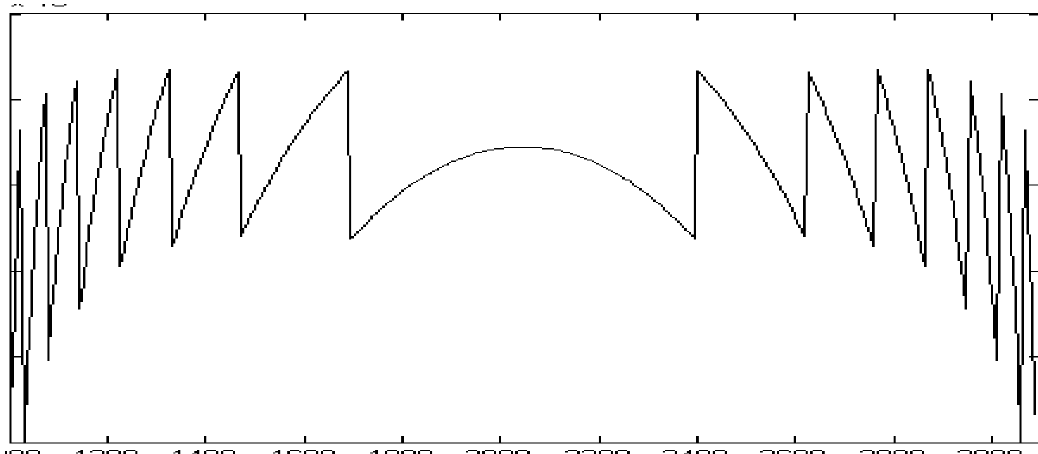
Figure 4-7 shows the relation of the maximum etched depth and step height of middle circle to the etch time, and Figure 4-8 shows the relation of step height of first ring and etched depth of middle circle to the etch time. The etched depth is proportional to the etch time, thus the etched depth can be predicted.



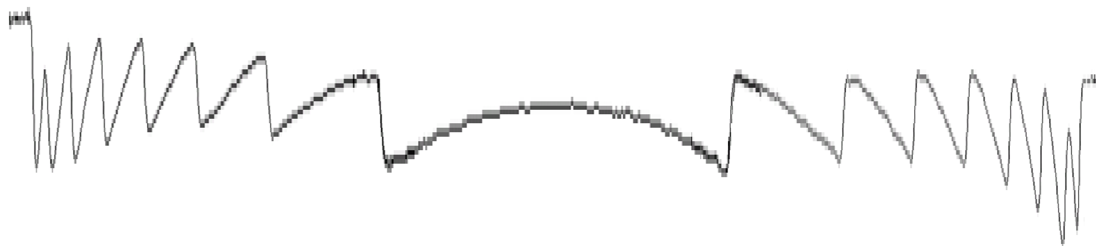
(a)



(b)



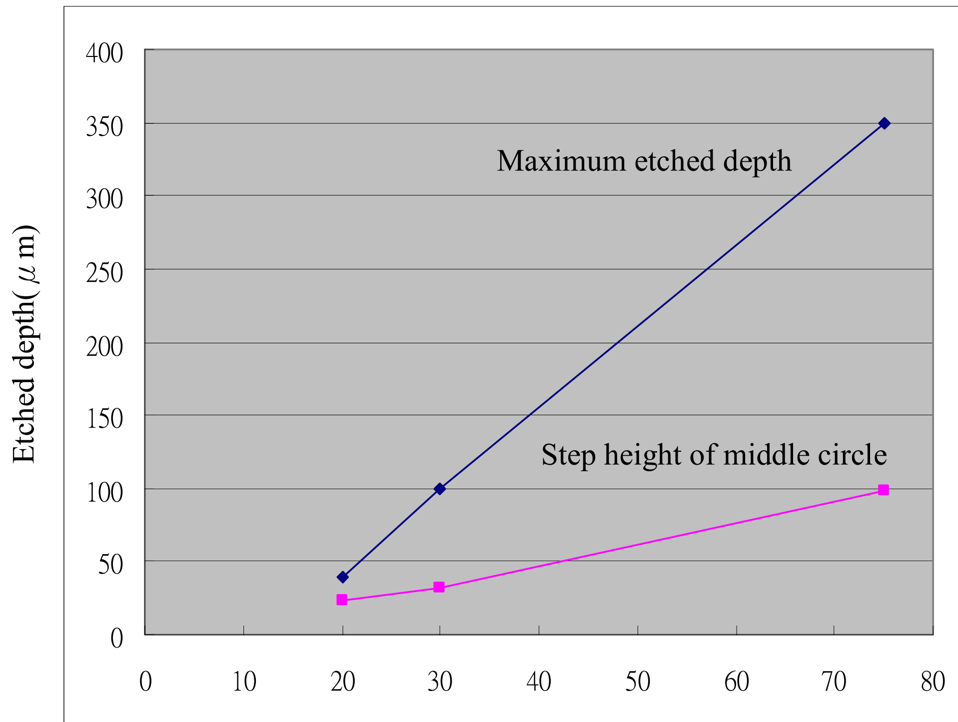
(c)



(d)

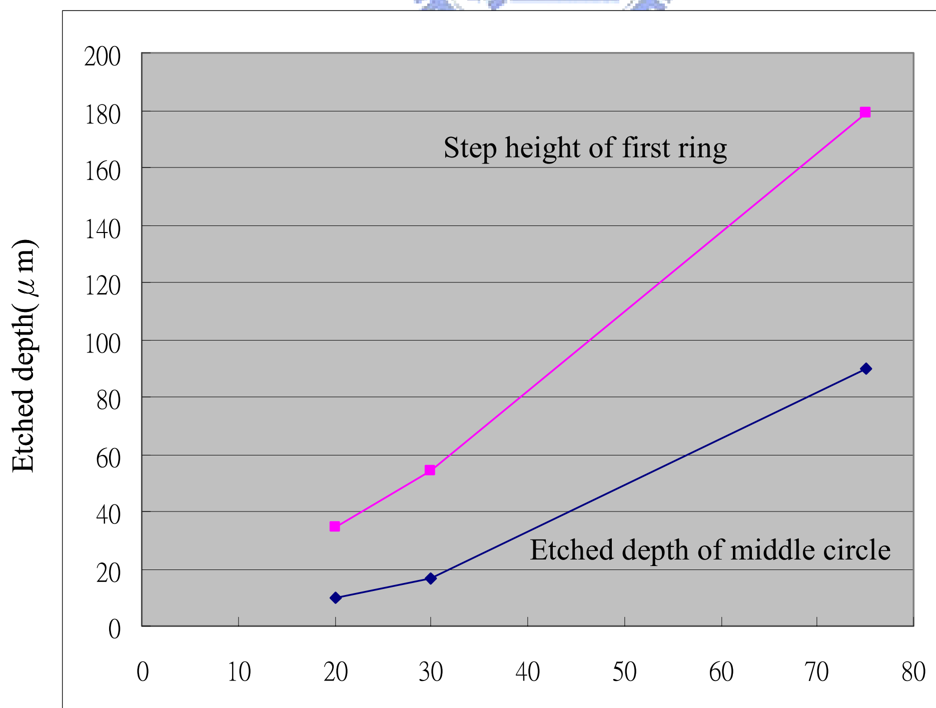
(e)

Figure 4-6: (a) Designed profile, (b) AFM profile after 20-minute FIB process, (c) compensated data. (d) AFM profile after 30-minute FIB process. (e) AFM profile after 75-minute FIB process



Etch time (minutes)

Figure 4-7: Maximum etched depth and step height of middle circle of silicon nitride.



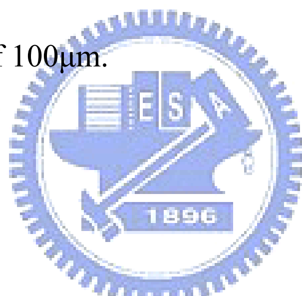
Etch time (minutes)

Figure 4-8: Step height of first ring and etched depth of middle circle of silicon nitride .

CHAPTER 5 Conclusion

5-1 Conclusion

In this thesis, a new gray-scale mask using FIB milling pattern on the silicon nitride layer is proposed and demonstrated. The fabrication process of the mask and the microlens is the same. Silicon nitride is used as mask and the material of microlens. The diameter of the microlens is 100μm, and the thickness of the microlens is based on the different lithography recipes and photoresist property. The photoresist model of AZ4620 has been made, and the FIB milled silicon nitride has been fabricated with the diameter of 100μm.



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5-2 Future work

In the future, the variation of FIB system is an issue to solve. And the FIB system should be well known to control the profile of the mask material layer. And the quartz can be used as the substrate with the advantage of simpler process, easy for photolithography, and more rigidity. This is because that the quartz substrate can be deposited membrane with higher temperature than glass. Quartz substrate is a kind of transparent material, so the backside etching is unnecessary.

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