Novel 3-Dimensional Photo Lithography using Built-in Lens Mask

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Introduction

3-dimensional lithography is demanded for advanced MENS or NEMS devices to obtain novel complex structures. Several methods had been proposed using beam processing such as laser, ion or electron beams and obtain micro-nano patterns. However, those conventional beam processes need beam scanning or substrate moving to fabricate 3-dimensional structures. On the other hand, we had been proposed novel 3-dimensional imaging by single shot exposure without beam scanning or substrate moving using multi-focusing built-in lens mask lithography by computational work [1,2].

In this work, we demonstrate 3-dimensinal photo lithography by experimental studies.

Mask design

The built-in lens mask is designed for pyramidal frame as shown in Fig. a). The seed patterns are placed along the 3-dimensional frame. The height of the pyramid is 40μm and the seed pattern is 500nm in square. The built-in lens mask for 3-dimensional imaging is designed by superposing the complex optical amplitude of the inverse Fourier transformation of the seed patterns [1].

Fig. 1 b) shows the layout of the built-in lens mask. The green pixels are transmittance windows without phase shifting, and the red pixels are π shifting windows.

Fig. 1 c) shows simulated optical intensity distribution in the resist using the built-in lens mask. The 3-dimensinal pyramidal frame image is formed in the resist.

Experiment

To obtain 3-dimensinal images by the built-in lens mask lithography, coherent illumination and small collimation angle is indispensable for optical exposure system. We newly set up proximity exposure tool having coherent illumination optics (λ =365nm) with small collimation angle (0.3 degree). Using the exposure tool, 3-dimensional photo lithography is examined. The exposure wave length is 365nm. The resist is SU-8.

Fig.1 d) shows experimental result of the 3-dimensional pyramidal frame using the built-in lens mask. To enhance rigidness of the resist, the resist is over exposed as usual. The pyramidal frame is successfully obtained using the built-in lens mask with single shot exposure without moving substrate or mask.

Conclusion

We firstly demonstrate 3-dimensional photo lithography by built-in lens mask with single shot exposure using proximity exposure system having coherent illumination optics. We believe the proposed method is one of the promising methods to fabricate novel 3-dimensional micro structures with simply and effectively.

Acknowledgements

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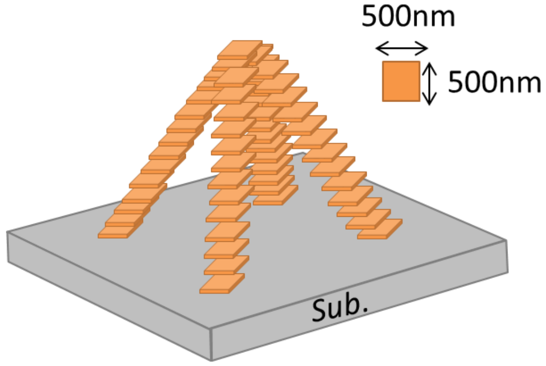
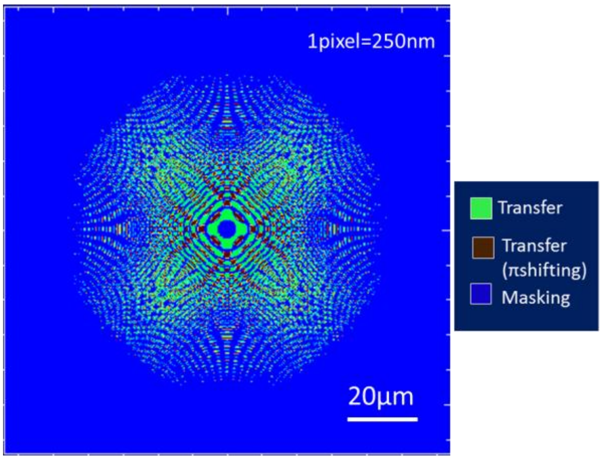
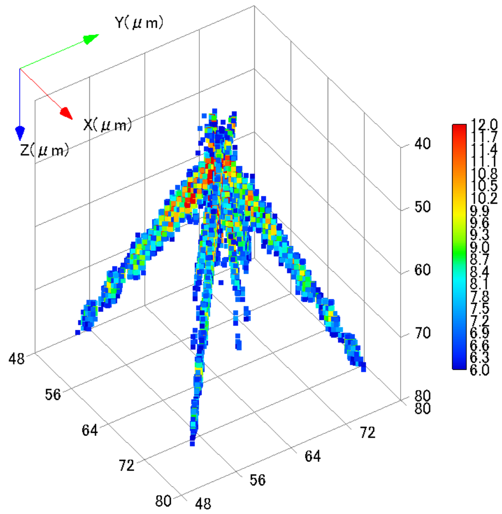
[1] T. Tanaka, et al., Microelectronic Engineering 158 (2016) 85.
[2] N. Ueda, et al., J. Vac. Sci. Technol. B 32 (2014) 06F702.



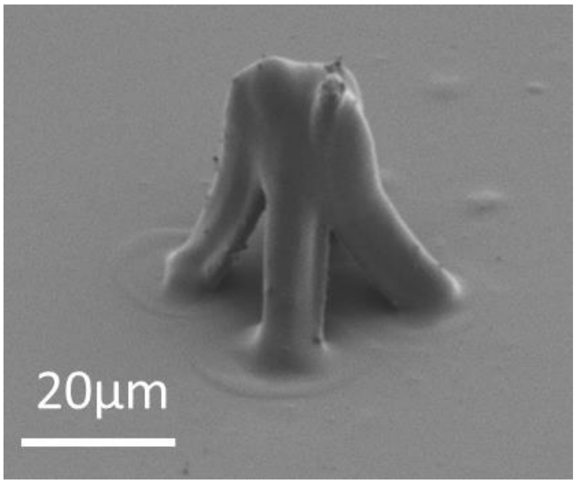
a) Schematics of seed patterns.
(The built-in lens mask for 3-dimensional imaging is designed by superposing the complex optical amplitude of the inverse Fourier transformation of the seed patterns [1].)



b) Layout of the built-in lens mask for pylamidal frame .
(The green pixels are transmittance windows without phase shifting, and the red pixels are π shifting. Blue area is masking.)



c) Simulated 3-dimensional optical intensity profile in the resist. Exposure wave length λ is 365nm.



d) Experimental result of resist structure using the built-in lens mask by coherent exposure system.
(λ=365nm, Resist: SU-8, 50µm on Si sub.)

Fig.1 Experiment and simulation results for 3-dimensional quadrangular pyramidal frame.