Computational study on novel proximity lithography for deep stepped substrate by Built-in Lens Mask (BILM)

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Introduction:

Novel photolithography using the built in lens mask (BILM) has deep focusing capability [1]. By modulation of the complex transmittance, the BILM realizes optical wave propagation to be focused without actual lens systems and arbitral deep forces depth could be obtained. Using the BILM, three dimensional (3-D) imaging was demonstrated in our previous work [2].

In this work, we newly investigate novel optical proximity lithography for deep stepped substrate using BILM.

Design of BILM for stepped substrate

The BILM emulates the complex transmittance of the optical wave plane $g(X,Y)$ for the image $u(z)$ at focus plane z, as if the wave plane is synthesized through lens systems, where the $g(X,Y)$ is obtained by Fourier Transform of the $u(z)$ excluding high frequency components. So, arbitral focus depth for each image $u(z)$ could be designed.

Figure 1 illustrates the schematics of the BILM for various focusing depth. The pattern is divided into small seed elements in various focus depths along the stepped substrate. The complex transmittance $g_0(X,Y)$ of the BILM is obtained by superposition for each seed patterns $g_i(X,Y)$ at various focus depth z_i, along the step.

$$g_0(X,Y) = \sum g_i(X,Y) \qquad 1).$$

To fabricate the BILM, the complex amplitude $g_0(X,Y)$ is digitized for the optical transmittance and the phase shifting[2].

Result and Discussion

Figure 2 (a) demonstrate digitized BILM for 2 levels in transmittance and 4 levels in phase shifting, which could be fabricated by the conventional phase shifting mask technology. The space optical intensity profile is demonstrated by computational works in Fig.2 (b). Along deep step as high as 40 um, fine pattern having around 1 um linewidth is successfully imaged. Figure 3 demonstrate line pattern imaging on curved substrate having 30 um in radius. On the curved surface, file pattern is successfully imaged using the BILM.

As demonstrated above, the BILM is applicable for micro scale various shaped substrate and depth of focuses for micro lithography such as micro fluid devices or MEMS devices.

Reference

[1] N. Ueda, et al., J. Vac. Sci. & Technol., **32** (2014) 06F702-5.
[2] N. Ueda, et al., EIPBN (San Diego, 2015) P06-01.

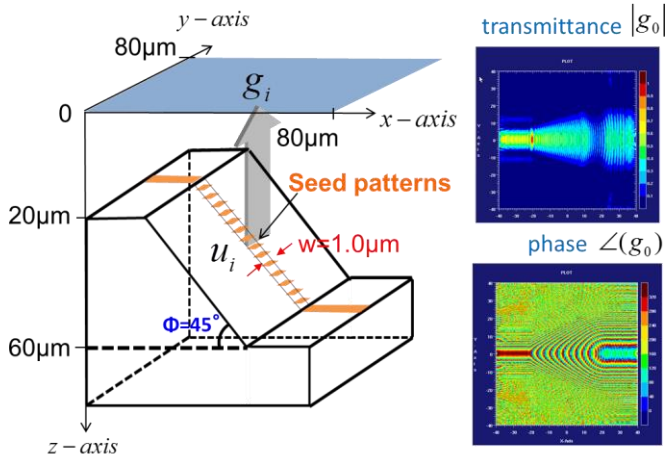
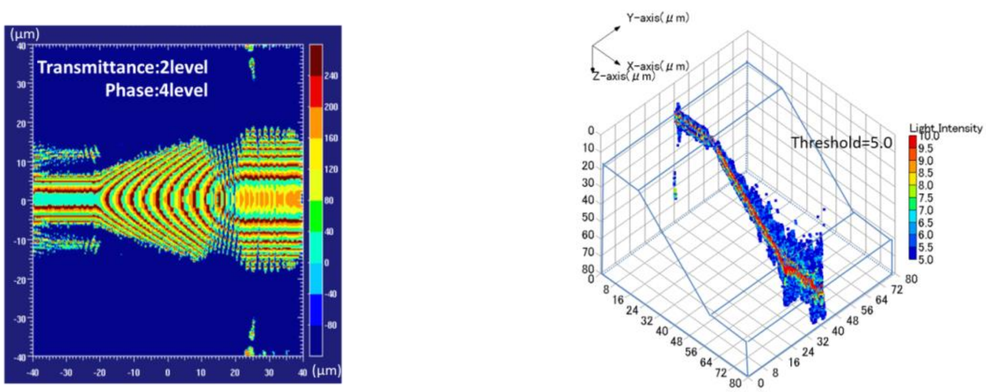


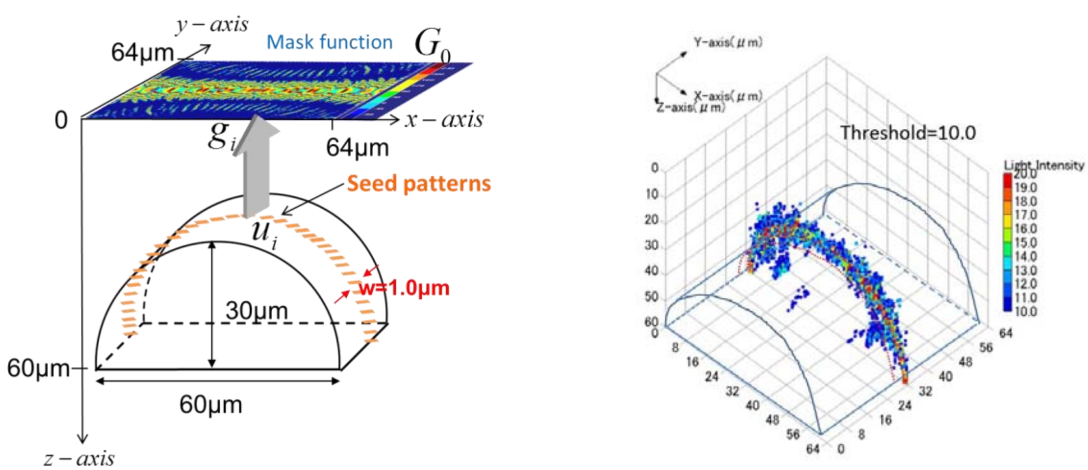
Figure 1. Schematics of the variable focusing built-in lens mask for stepped substrate. The line pattern is divided into small seed patterns in various focus depth. The complex transmittance of the BILM is superposed of each complex transmittance of the seed patterns.



a) Digitized mask layout

b) Optical intensity profile

Figure 2. Space optical intensity profile for stepped substrate by BILM lithography.
The line width is 1.0um and the step height is 40um. The wave length of the incident light is 365nm.



a) Schematics for curved substrate

b) Optical intensity profile

Figure 3 Space optical intensity profile for curved substrate by BILM lithography.
The line width is 1.0um and the radius of cylinder is 30um. The wave length of the incident light is 365nm.