Computational study on 3-Dimensional Imaging by Advanced Built-in Lens Mask (BILM) Lithography

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1. Introduction: Three dimensional (3-D) imaging is demanded to fabricate fine and 3-D flow channels for advanced micro-nano fluid devices. One of the typical approaches to fabricate the 3-D structures is the use of micro electro mechanical system technology based on semiconductor lithography. However, the process becomes complex and requires numbers of process steps. On the other hand, 3-D printer technology based on additive manufacturing is recently progressed to obtain complex structures for prototyping. Those technologies are not suitable for mass production in cost effectively, because the throughput is not always enough for numbers of additive layers.

In this work, we newly propose novel photolithographic method for 3-D imaging by advanced built-in lens mask (BILM) lithography to realize multiple focusing without hard lens systems. The performance is examined by computational lithographic work.

2. 3-Dimensional Imaging by Advanced BILM : The BILM emulates the complex transmittance amplitude $g(X,Y)$ of the optical wave plane for the pattern image $u(z)$ by projection lens systems. The $g(X,Y)$ is obtained by Fourier Transform of the $u(z)$ excluding high frequency components. Using the BILM, focus position z could be designed for voluntary patterns by conventional proximity exposure systems. The performance was confirmed by both computational and experimental works in our previous reports [1].

By using the BILM, 3-D imaging is approached by multiple focusing. Figure 1 illustrates the basic concept of the advanced BILM for 3-D imaging. The complex transmittance $G(X,Y)$ of the multiple focused is superimposed each complex amplitude for *n*-th amplitude $g_n(z)$ for the *n*-th pattern at the focus depth z_n,, having phase shifting $\Delta\theta_n$ to avoid interference with each other.

$$G(X,Y) = \sum_n g_n e^{i\Delta\theta n} \qquad 1).$$

3. Result and Discussion: To confirm the 3-D imaging, the optical intensity in the space is examined by computational lithography. The ‘H’ shaped structure is examined as illustrated in Fig.1. The ‘H’ shaped structure is divided by the 3 focus planes. The complex amplitude $g_n(z)$ for the patterns $u_n(z)$ on each focus plane are superimposed on the built-in lens mask. Figure 2 a) shows the optical intensity profiles exposed through the built-in lens mask, where the complex amplitude for each focus planes is simply superimposed. The ‘H’ shaped image is decomposed due to interference by wave planes from each component. On the other hand, 3-D optical image is successfully obtained with phase shifting by superimposing operation to avoid interferences as demonstrated in Fig.2 b). Not only the ‘H’ shaped imaging but also Y shaped imaging is confirmed. The result shows the high throughput 3-D micro-nano imaging by the advanced BILM lithography is promising for micro fluid devices and other applications.

Reference

[1] N. Ueda, et al., J. Vac. Sci. & Technol., **32** (2014) 06F702-5.

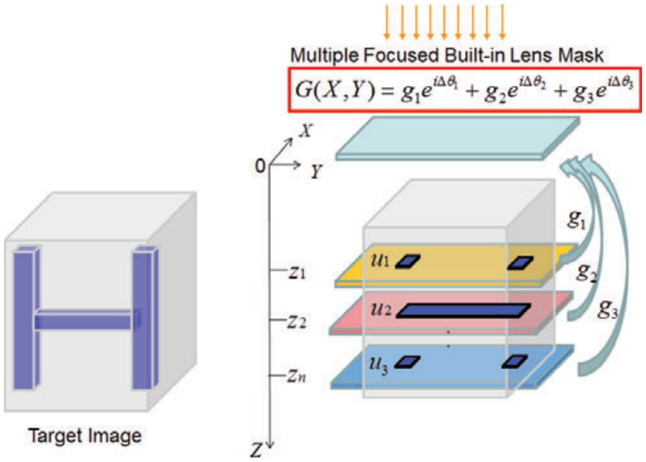
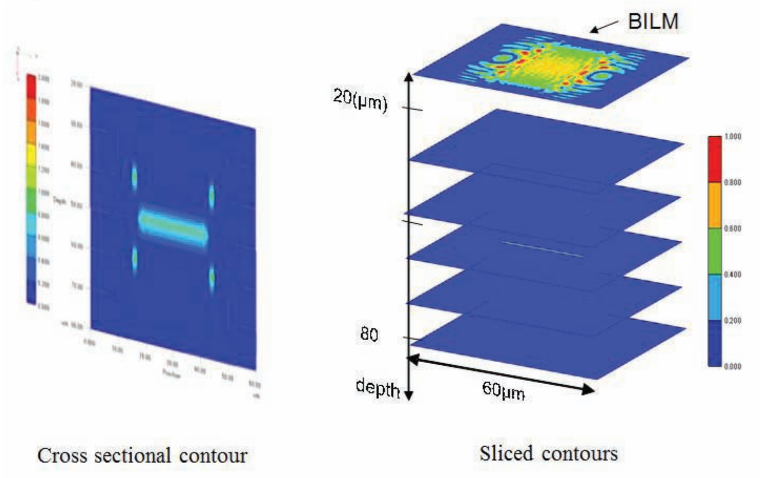
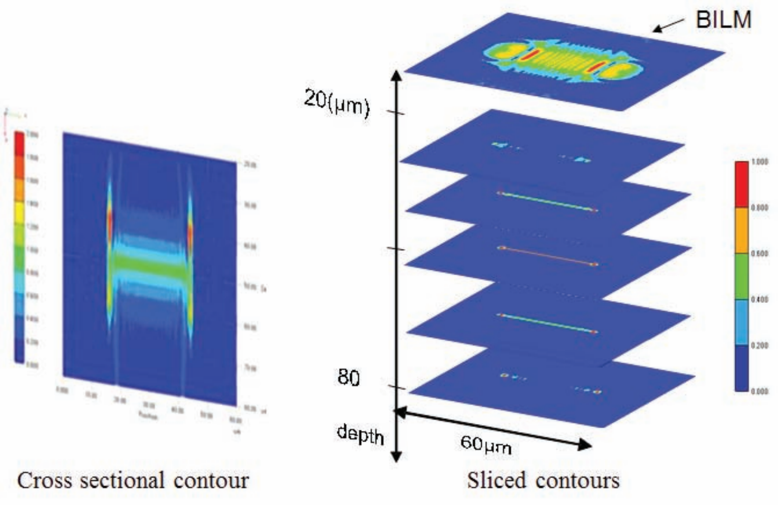


Figure 1. Schematics of the multiple focusing built-in lens mask for 3-D imaging. For instance, 'H' shaped structure is divided by the 3 focus planes. The Fourier transferred complex amplitude $g_n(z)$ for the patterns $u_n(z)$ on each focus plane are superimposed on the built-in lens mask.



a) Without phase shifting.



b) With phase shifting $\Delta\theta_n$ to suppress interference.

Figure 2. Optical intensity profiles for the 'H' shaped 3-D structure. The designed feature size of the 'pillar' and the 'beam' of the 'H' structure are 500nm. The wave length of the incident coherent light is 365nm.