Computational study on micro 3-dimensional imaging using novel photolithography

Daiki Sugihara, Akio Misaka, Kousuke Sato, Hisao Kikuta, Hiroaki Kawata, Masaaki Yasuda, Masamitsu Shirai, Masaru Sasago, Yoshihiko Hirai*
Graduate School of Engineering, Osaka Prefecture University, Sakai, Japan

*E-mail: hirai@pe.osakafu-u.ac.jp

Introduction

3-dimensional structures are demanded for advanced MENS or NEMS devices to realize functional structures such as bio-mimetics structures. Several methods had been used to fabricate 3D structures using 3D printers, beam processing, etc. However, those conventional processes need scanning process or substrate moving to fabricate 3-dimensional structures, which are not always efficient processes.

To overcome the issues, we had been proposed novel 3-dimensional imaging by single shot exposure without scanning process or substrate moving by multi-focusing built-in lens lithography technique and conformed 3-dimensional imaging in experimentally [1,2].

In this work, we report further possibility on the 3-dimensional imaging using the built-in lens lithography by computational works.

Mask design

To obtain 3-demensional image, the 3-D structure is divided into seed elements and the seed images are superimposed utilizing multi-focusing function of the built-in lens mask[2]. The complex transmittance g_0^* of the built-in lens mask is designed as:

$$g_0^* = \sum_i g_i^* e^{\Delta\theta_i} / N \qquad 1),$$

where g_i^* is the optical complex amplitude for i-th seed pattern and $\Delta\theta_i$ is the phase offset for each seed pattern to avoid interference from each other.

Result and Discussion

Various 3-D imaging are examined by computational works. Figure 2 demonstrates cylinder structure. When the seeds are placed cylindrically, unexpected ‘axis’ rod and ‘ring’ are induced because the optical path length from each seed becomes the same and it is focused on the axis as demonstrated in Fig.2 a). To avoid the unexpected image, the seeds are placed spirally as illustrated in Fig. 2 b) to eliminate interference. The axial rod and ring images are eliminated and micro cylinder pattern is obtained. In Fig. 3, crossing lines are demonstrated. When the seeds are placed on interfering position, each line are destructive as shown in Fig.3 a). After optimization of each phase of the seed and the position, multiple crossing structures in space are successfully obtained as demonstrated in Fig.3 b).

As demonstrate, 3-dimensional photo lithography is examined using built-in lens mask with single shot exposure. We believe the proposed method is one of the promising methods to fabricate novel 3-dimensional micro structures with simply and effectively. Furthermore discussions on layout optimization of the seeds and limitations will be discussed.

[1] T. Tanaka, et al., J. Vac. Sci. Technol. B 32 (2014) 06F702..
[2] N. Ueda, et al., J. Vac. Sci. Technol. B 35 (2017) 06G308.

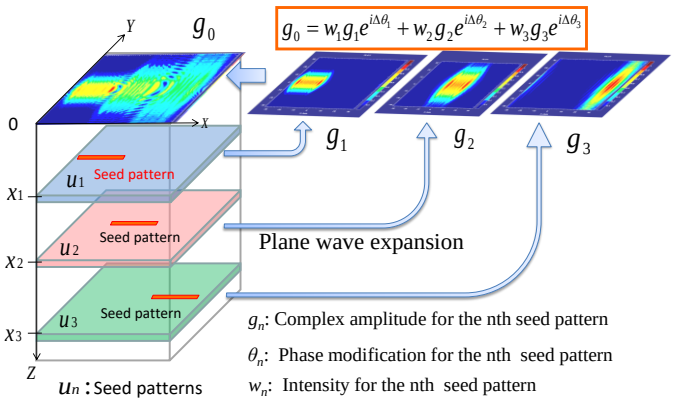
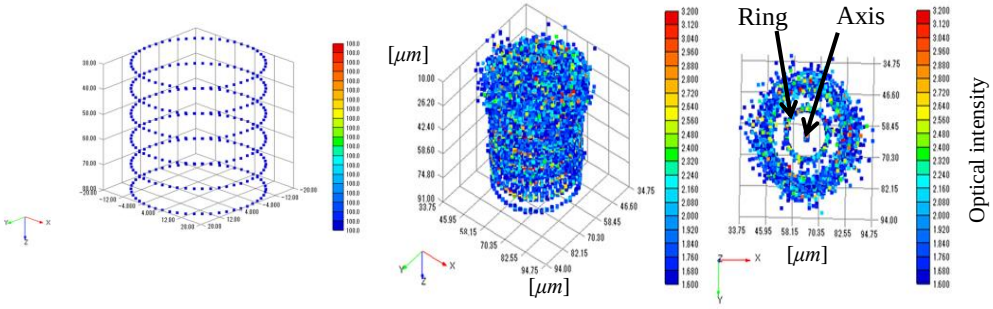
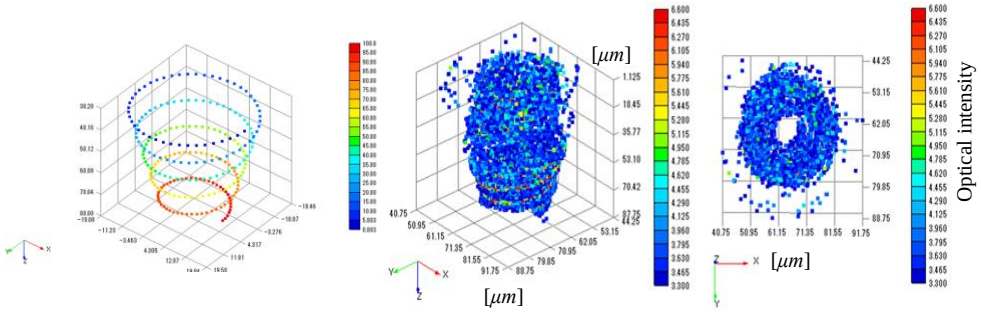


Figure 1. Schematics of 3-D imaging by multiple seeds pattern using built-in lens lithography [1,2]



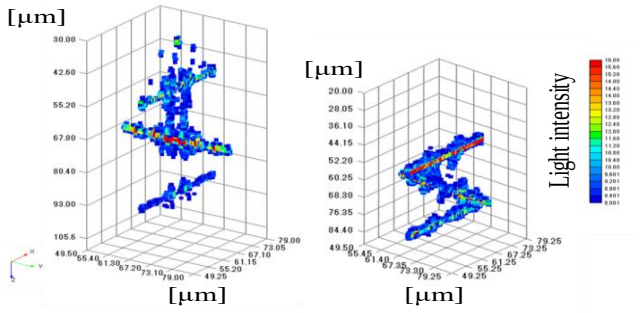
a) Using ring seeds (Left: seed layout, middle and right: space optical intensity)



b) Using spiral seeds (Left: seed layout, middle and right: space optical intensity)

Figure 2 Optical images for micro cylinder patterns in various seed layout..

For the ring seeds, 'axis' and 'ring' apparel due to interference. Using spirally mounted seeds to cancelation of the interference, those are eliminated. (λ :365nm, seed: 300nm square, cylinder radius :20μm, Length : 50μm)



a) Gap: 30μm b) Gap: 15μm

Figure 3 Optical images for special micro wires in crossing layout..

By optimizing the seed size, spacing, interference is eliminated and defects are disappeared.

(λ :365nm, seed: 300nm lines)