20p-C4-6

Supplementary Zones-surrounded Fresnel Zone Plate

Yen-Min Lee[1], Szu-Hung Chen[2], Chen-Pin Hsu[3], Pei-Chuen Chiou[1], Kuen-Yu Tsai[4], Tien-Tung Chung[5], Cheng-Han-Tsai[1], Zhan-Yu Liu[1], and Jia-Han Li[1,*]

[1] Department of Engineering Science and Ocean Engineering, National Taiwan University
[2] National Nano Device Laboratories, National Applied Research Laboratories
[3] Institute of Nanoengineering and Microsystems, National Tsing Hua University
[4] Department of Electrical Engineering, National Taiwan University
[5] Department of Mechanical Engineering, National Taiwan University
E-mail: *jiahan@ntu.edu.tw

1. Introduction

The supplementary zones surround an ordinary Fresnel Zone Plate (FZP) are used to improve the optical resolution at focus. Based on the Fresnel-Kirchhoff diffraction formula, an optimization model is used to design the supplementary zones-included FZP (SZFZP). The model will be examined by comparing the simulations with the measurements in visible region. Then, this model is used to design the SZFZP for extreme ultraviolet (EUV) light. The ability to fabricate the FZP for applications in EUV light will be demonstrated. In addition, the simulated performance of the SZFZP in EUV region will be shown in this paper.

2. Model Verification in Visible Region

We designed the standard FZP and the SZFZP for 633 nm wavelength (λ). The material of the samples is photomer 3015 epoxy acrylates with fused silica substrate. Our standard FZP is designed as a 5-rings FZP. In which its zone widths decreases farther from the center and its outermost zone width is 300 nm. For the supplementary zones, the zones are broadened farther from the inner rings and each of them is wider than 300 nm. The measured focus for the SZFZP has better resolution and stronger intensity than the measurement from the standard FZP are shown in Fig. 1(a). It is also shows good match between the simulations and the measurements in Fig. 1(b) and 1(c) excluding the measured noises.

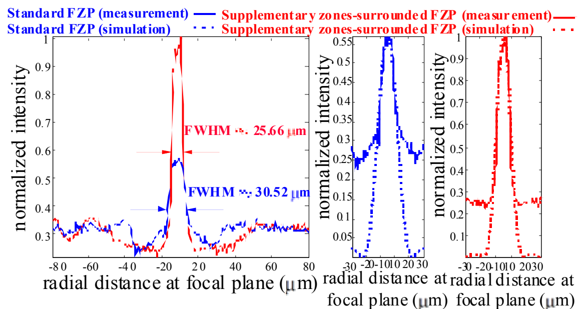

Fig. 1 Lateral profile of the red light focus, where (a) stands for the measurements, (b) stands for the simulated and measured profiles for the standard FZP, and (c) stands for the simulated and measured profiles for the SZFZP.

3. Optimized FZP in EUV region

Our standard FZP for λ = 13.5 nm is designed as a 411-rings FZP, and its outermost zone width is 50 nm. For SZFZP, 211 supplementary zones are surrounded, and all supplementary zones are always wider than 50 nm. The fabricated SZFZP for EUV can be seen in Fig. 2, where the zone material is NiSi with silicon substrate.

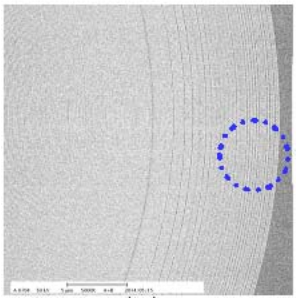

Fig. 2 Fabricated SZFZP for λ = 13.5 nm.

The monochromatic simulations shown in Fig. 3(a) indicate that the peak intensity of the SZFZP has stronger intensity and better resolution. Also, the simulated focus from SZFZP for EUV light contains 2% bandwidth is shown in Fig. 3(b). The findings indicate that 2% bandwidth will affect the EUV image since the intensity goes down severely for just slight wavelength shift.

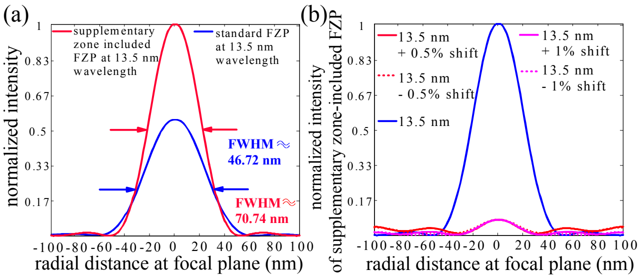

Fig. 3 Lateral profile of the simulated EUV light focus. (a) Comparisons between the standard FZP and the SZFZP. (b) Focuses of the SZFZP when EUV light contains 2% bandwidth.

4. Conclusions

We have demonstrated that the SZFZP can have better resolution and higher intensity than FZP in visible region. A SZFZP for EUV light is fabricated and its simulation shows that the promising resolution enhancement. Further work in this study can be useful for EUV focusing lens applications.

Acknowledgements

This work was supported by the National Science Council of Taiwan (NSC 102-2120-M-009-005 and 102-2221-E-002-006).