# FDTD study of near field phase-shifting lithography for high-precision fabrication of nano-image profiles

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Following the recent advances in microlithography, the patterning and fabrication of microprocessors and memory chips with critical feature size less than 100 nm can be realized by utilizing ArF based photolithography and direct e-beam lithography (EBL) [1]. By employing optical enhancement schemes such as phase shift mask [2], off-axis illumination, and optical proximity correction, ArF based photolithography has the potential of reaching a 65-nm technology node for the next generation. It has capacities of high manufacture throughput. But optical lithography steppers are too expensive for research or industrial use. EBL techniques rely on a serial fabrication paradigm, which makes the time required to produce structures too long for practical industrial applications. It is also too expensive for research or industrial use. From this it can be seen that the development of a lithographic method that combines the advantages of high-volume-production over a large area with lower production cost to allow for the producing of simple devices, for example line or hole or IDT devices, is widely anticipated. The transparent mask used in near field phase-shifting lithography (NFPSL) [3] process can induce abrupt changes in the phase of the light used for exposure, which, due to destructive optical interference at the edges of the circuit features, cause optical attenuation. Consequently a narrower gap must be developed. NFPSL is a low-cost, high-throughput production process for nano-structure pattern transferred over large areas. When the image profile can be simulated and precisely fabricated, the arbitrary nano-image profiles will be easily controlled.

In this work, the nano-image profiles transferred through near field phase-shifting mask (NFPSM) at various exposure-energy-intensity (EEI) are studied by the finite-difference time-domain (FDTD) method and precisely fabricated. Transferred energy-intensity distribution (TEID) in the resistor through NFPSM at the wavelength of 248 nm as shown in Fig. 1 are sharply simulated by FDTD method. As shown in Fig. 2, the TEID is simulated at the boundary between the mask and the resistor, and the pattern widths are fabricated and clearly fitted to the simulation results. The pattern widths in the photo resistor are dependent on the various EEI. The simulation of the pattern widths at the various distances under the boundary is shown in Fig. 3 when using the various EEI. The image profiles are dependent on the EEI. The imaging profile with the linewidth of 100 nm is fabricated and clearly fitted to the simulation result when using the exposure-energy-intensity of KrF laser of 2 mJ/cm$^2$. Therefore, the arbitrary nano-image profiles can be easily fabricated.

. References

[1.] H. Elsner , H.-G. Meyer, Microelectronic Engineering 57–58 (2001) 291.
[2.] Fu-Der Lai, J. Vac. Sci. Technol. B22(6) (2004) 3097.
[3.] Joana Maria, Seokwoo Jeon, John A. Rogers, Journal of Photochemistry and Photobiology A: Chemistry 166 (2004) 149.

The author is grateful to the support of the National Science Council at Taiwan, under contract No. NSC 95-2221-E-327 -041

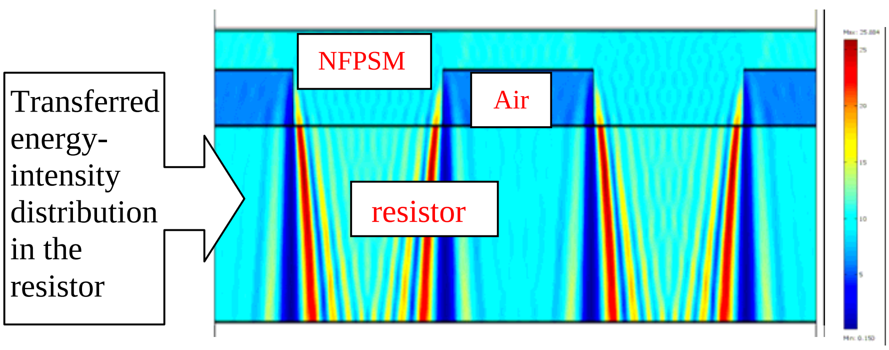



**Fig. 1** FDTD study of energy-intensity distribution in the resistor transferred through near field phase-shifting mask at the wavelength of 248 nm.

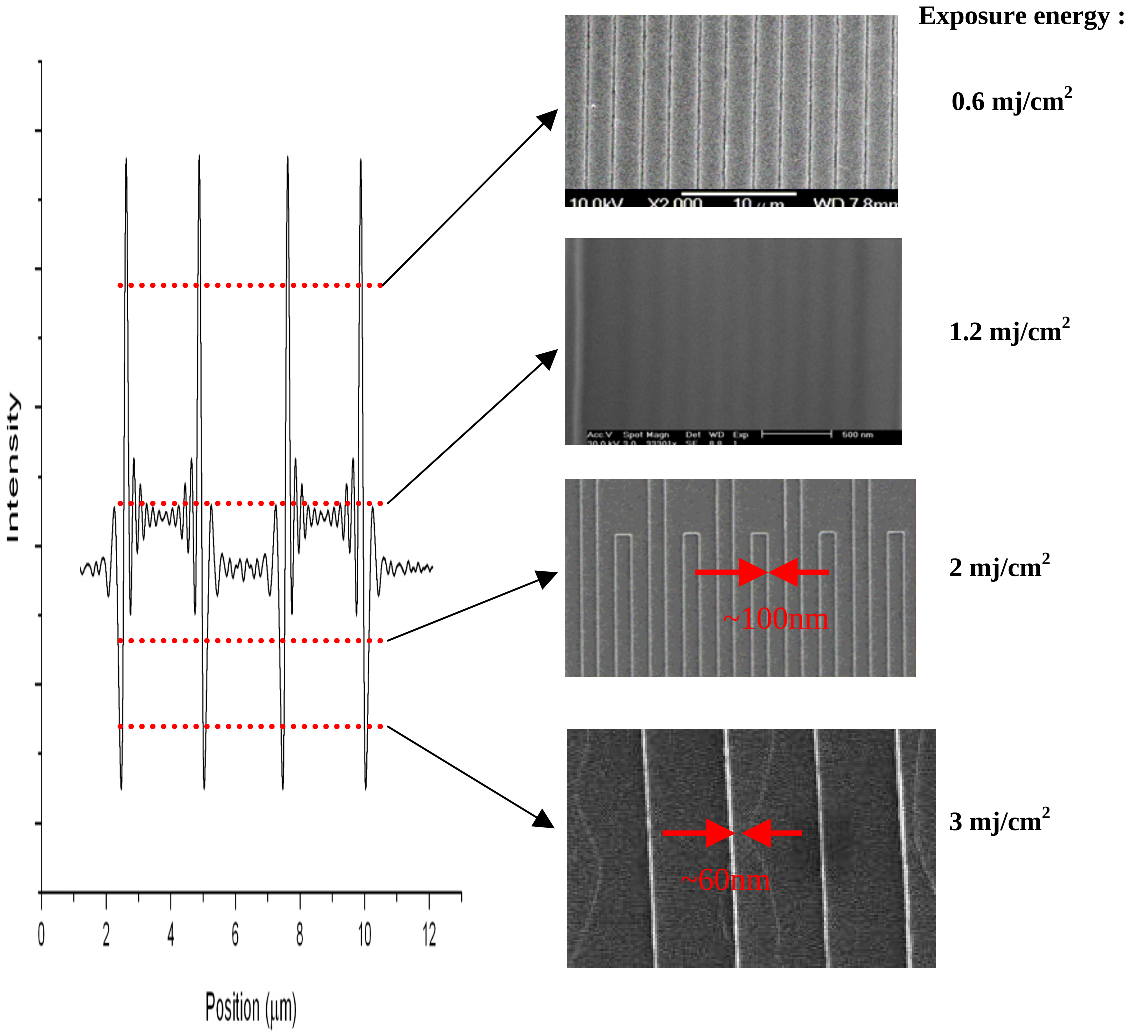
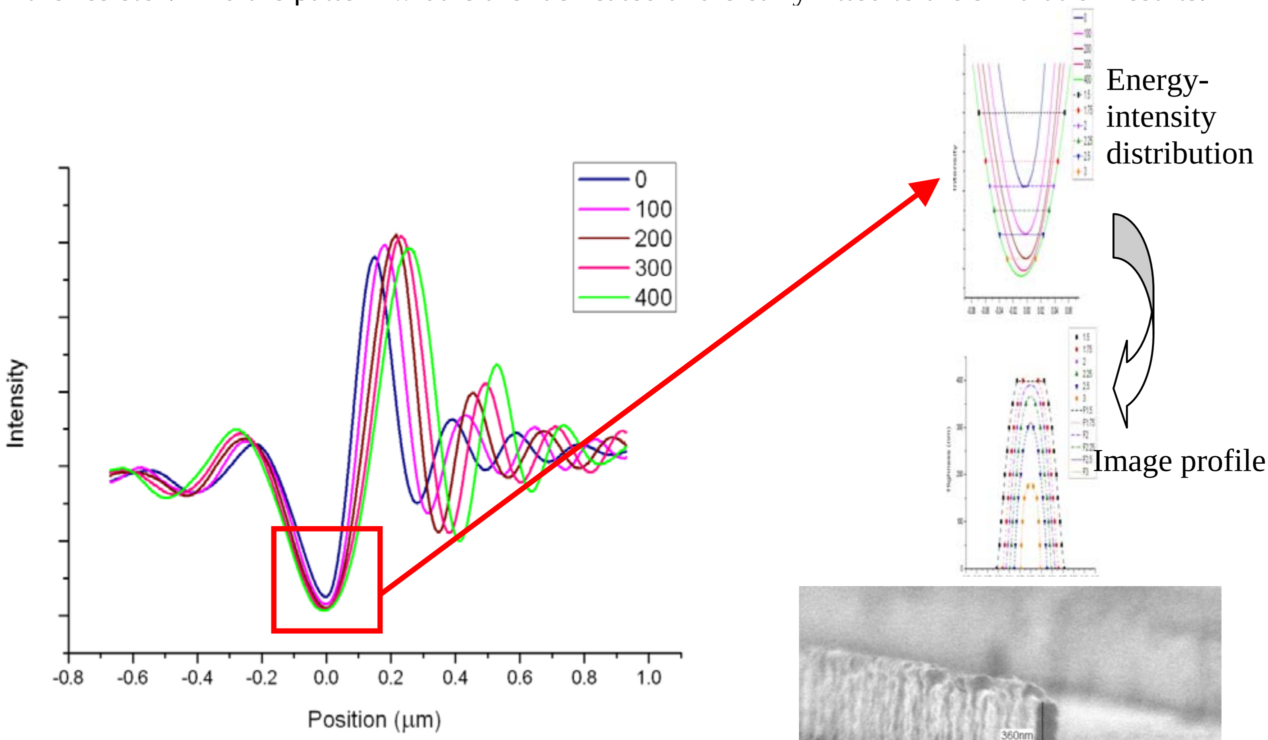



Fig. 2 The transferred energy-intensity distribution simulated at the boundary between the mask and the resistor. And the pattern widths are fabricated and clearly fitted to the simulation results.



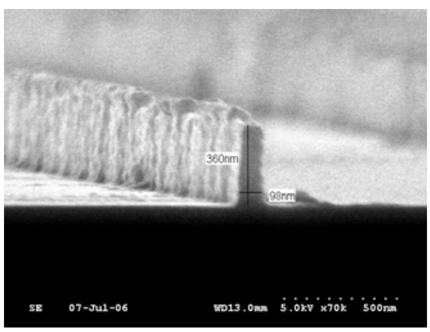




**Fig. 3** The image profiles dependent on the EEI. The imaging profile with the linewidth of 100 nm is fabricated and clearly fitted to the simulation result when using the exposure-energy-intensity of KrF laser of 2 mJ/cm$^2$.