Parallel near field optical lithography with sub wavelength resolution using a massive array of bowtie antennas

A. Datta[a], X. Wen[a,b], L. M. Traverso[a], X. Xu[a*], E. E. Moon[c]
[a] *School of Mechanical Engineering and Birck Nanotechnology Center, Purdue University, West Lafayette, Indiana 47906*
[b] *Department of Optics and Optical Engineering, the University of Science and Technology of China, Hefei, Anhui 230026, China*
[c] *Department of Electrical Engineering and Computer Science, Massachusetts Institute of Technology, Cambridge, Massachusetts 02139*
([*]Email: xxu@purdue.edu)

Recently in the field of nano-optics, optical antennas have received considerable attention due to their capability of enhanced transmission of light and generating sub-wavelength optical spots. The applicability of such antennas have been explored in areas such as data storage, lithography, and scanning probe microscopy. One of the challenges associated with the antennas is maintaining the working distance in the range of tens of nanometers, beyond which the field intensity exponentially decreases. To address this issue, an interferometry based spatial phase imaging system (ISPI) was used[1] which consisted of a pair of chirped gratings. This system was successfully used to control the working distance of the antenna in the nanometer range. To demonstrate the applicability of antennas in lithography, a mask of metal film was created on a quartz substrate with bowtie antennas milled in it. The ISPI system was integrated in the mask which allowed for detecting the gap between the mask and a substrate coated with photoresist. Scanning the substrate along with exposing the photoresist through the bowtie antennas generated lithography patterns and features as low as $\frac{\lambda}{15}$.[2]

This work deals with expanding the capability of the lithography process by incorporating hundreds of bowtie antennas simultaneously in the mask. This would allow for parallel fabrication of the lithographic patterns on a massive scale. The main challenge in tackling this problem was maintaining a consistent gap between the different bowtie antennas. This was done by using several pairs of ISPI gratings and adjusting the tilt of the mask relative to the substrate iteratively to ensure that the gap is same for each of the ISPI grating. With this method we were able to produce lithographic patterns in a parallel manner as shown in Figure 1. The precise gap control also allows us to control the thickness of the lithographic lines by adjusting the scanning speed and the incident power. These results show that the parallel route has a great potential for an increased efficiency in nanolithography processes.

---

[1] X. Wen, L. M. Traverso, P. Srisungsitthisunti, X. Xu and E. E. Moon,, *J. Vac. Sci. Technol.* B, **31**, 041601 (2013)

[2] X. Wen, L. M. Traverso, P. Srisungsitthisunti, X. Xu and E. E. Moon, *Appl. Phys. A*, **117**, 307 (2014)

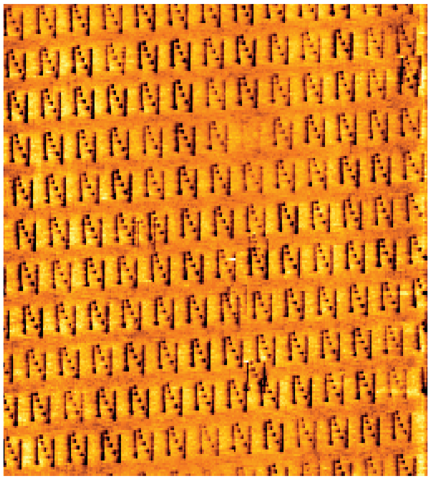

Figure 1: An AFM image of the parallel lithography process. The "N" shaped lines are produced by exposing the photoresist through an array of bowtie antennas.