Sub-wavelength Proximity Nanolithography using Plasmonic Lens

Sungkyu Seo*, Hyun Chul Kim and Mosong Cheng
Department of Electrical and Computer Engineering
Texas A&M University, College Station, TX 77843-3128

This paper presents a sub-wavelength proximity nanolithography based on a Plasmonic Lens (PL) which consists of titanium (Ti) nano-structures on a fused silica substrate. Since it was proposed that the optical near field can be enhanced by a metal layer whose dielectric constant is negative [1], plasmonic sub-wavelength lithography techniques have been widely investigated [2]. So far these techniques are similar to contact lithography except that they insert a metal film (e.g. Ag) between a mask and a resist layer to improve the resolution and the working distance [3]. The gap between the mask and the resist, namely, the Working Distance (WD), is still a fraction of the wavelength so the imaging of a non-planar wafer surface is very challenging.

In this paper, we report a proximity lithography technique that uses a PL to print sub-100nm features with a WD of 1700nm. The PL focuses a 405nm wavelength violet laser beam to a sub-100nm spot that is 1700nm away from the PL. The PL, whose SEM is shown in Fig.1, consists of equally spaced four ring apertures (150nm width, 3um spacing) and a central hole (150nm diameter) in a 60nm thick Ti film on a fused silica substrate. The PL was fabricated by E-Beam Lithography (EBL) and Reactive Ion Etching (RIE). When a collimated 405nm violet light illuminates the back of the fused silica, a tiny focused spot in the Fresnel diffraction region is formed and exposes a 200nm thick g-line resist layer (S1805, Shipley) on a Si sample. An electronic shutter adjusts the exposed dose. The positions of the exposed spots and the gap (WD) between the PL and the resist are controlled precisely by computer based 6-axis nano-stage system (NanoMax-HS, Melles Griot). Fig. 2 shows that 132nm spots were printed, which is far below the diffraction limit and agrees well with our finite-difference time domain (FDTD) simulation results. The printing of sub-100nm features will be described, the exposure latitude and the depth-of-focus will be also evaluated.

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[1] J. B. Pendry, “Negative refraction makes a perfect lens”, *Phys. Rev. Lett.*, Vol. 85, pp. 3966-3969, 2000.

[2] D.O.S. Melville and R. J. Blaikie, “Super-resolution imaging through a planar silver layer”, *Optics Express*, Vol. 13, Issue 6, pp. 2127-2134, 2005.

[3] N. Fang, H. Lee, C. Sun, X. Zhang, “Sub-Diffraction-Limited Optical Imaging with a Silver Superlens”, *Science*, Vol 308, pp. 534-537, 2005.

* E-mail: seo_sungkyu@tamu.edu , Phone: (979) 458-1555

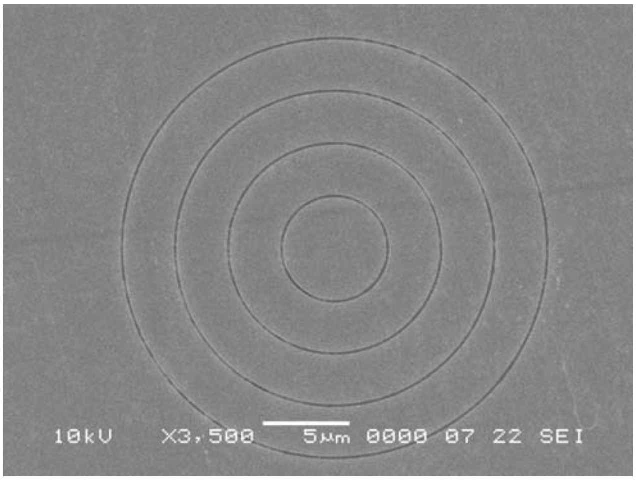

Fig. 1. SEM of the Plasmonic Lens (PL). The PL consists of equally spaced four ring apertures (150nm width, 3um spacing) and a central hole (150nm diameter) in a 60nm thick Ti film on a fused silica substrate.

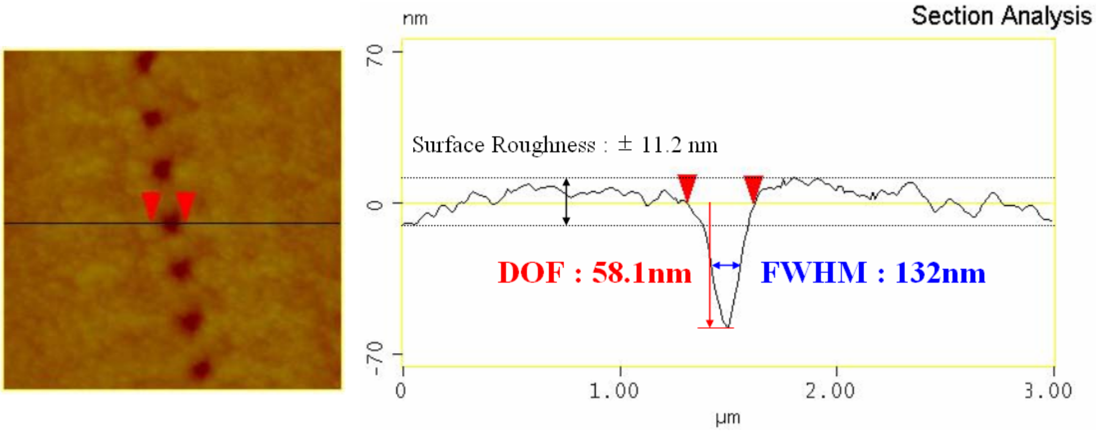

Fig. 2. AFM of printed spots. The PL imaged 132nm wide (at full wave half maximum) and 58.1nm deep spots in a 200nm thick g-line resist (S1805) on a Si sample exposed with 405nm violet laser.