High-Numerical Aperture Imaging using Plasmonic Mirrors

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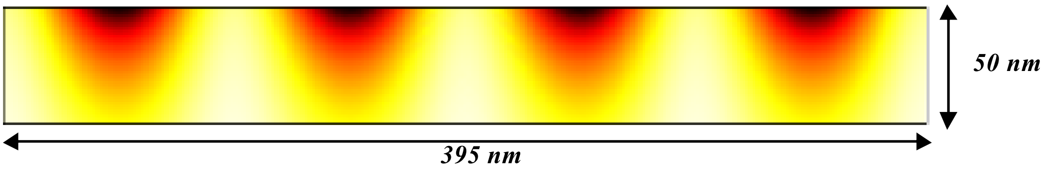
It is very difficult to achieve a high depth of focus for lithographic imaging at numerical apertures (NAs) higher than the refractive index of the photoresist; higher NAs causes the waves to be evanescent and only allows surface imaging at best [1].

In 2007, Blaikie et al. [2] proposed the idea of using metallic under-layers as super-mirrors to enhance the evanescent fields giving a better depth of focus for high-NA imaging. This was later analytically demonstrated by Arnold et al. [3]. The imaging relies on the fact that the negative real part of the permittivity of metal allows reflections that are much larger than unity in the evanescent regime, and examples of the expected intensity profiles in 50-nm thick resist at an NA=1.85 in the system are shown in Fig. 1. A high contrast image does not extend all the way into the resist layer with an index-matched bottom layer, but it does with the plasmonic bottom layer added (silver, $\epsilon = -2.7 + 0.23i$). The presence of an underlying plasmonic layer changes the amount of energy that is extracted from the reflected wave; this energy is then redistributed in the imaging area allowing a much more desired image profile.

To test this concept we will describe a new cost-effective technique to perform high-NA interference lithography based on the Lloyd's mirror that requires only the use of a high index prism, index matching liquid and a coherent laser source. The method is similar to other two-beam solid-immersion lithography schemes [1,4], but eliminates the need for beam splitters, a beam block and some steering optics. Yttrium Aluminum Garnet (YAG) is used as the prism material, which has a refractive index of 1.87 at 365nm, and the idea is easily extended for 193 nm imaging using a Lutetium Aluminum Garnet (LuAG) prism material [4].

(a) *Without plasmonic reflector*



(b) *With plasmonic reflector*

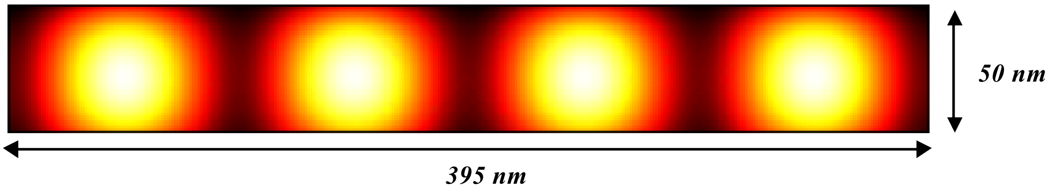


Figure 1 – Interference lithography test images at NA = 1.85 with λ = 365nm (a) without a plasmonic reflector and (b) with a plasmonic reflector

[1] B. W. Smith, Y. Fan, J. Zhou, N. Lafferty, and A. Estroff, Proc. SPIE 6154 (2006)
[2] R. J. Blaikie, M. M. Alkaisi, S. J. McNab, D. O. S. Melville, Int. J. Nanoscience 3, 405-417 (2004)
[3] M. D. Arnold, R. J. Blaikie, Optics Express 15, 11542-11552 (2007)
[4] J. Zhou, N. V. Lafferty, B. W. Smith, and J. H. Burnett, Proc. SPIE 6520, 65204 (2007).