Super-resolution Imaging with Photochromes and Plasmons

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The driving force behind improvements in transistor density is the ability to accurately create patterns at the small dimensions required; with state of the art now requiring feature sizes below 45 nm. The projection lithography system, involving a far-field source, a mask and a focusing lens has enabled phenomenal improvements in resolution over the past 40 years. However projection lithography faces large obstacles to further improvements as diffraction effects degrade image quality when imaging below the system wavelength and no suitable wavelength has been found below 193 nm. An alternative is to bypass the diffraction limit by making use of the optical near-field, where the high spatial frequency information is maintained but the light intensity decay is evanescent.

Here we first discuss Absorbance Modulation Optical Lithography (AMOL) [1,2] which makes use of a photochromic layer as a mask; this is placed directly on to the photoresist which will store the image. The absorbance of the photochromic layer is dependent on the incident light intensity, and with two competing far-field sources the desired mask apertures may be created; one of these sources can also produce a sub-diffraction limited image in the photoresist. The reversible nature of the photochromic layer allows a return to the initial state and therefore multiple imaging steps. This system overcomes the diffraction limit as well as some of the issues surrounding near-field lithography such as the positioning and alignment of the mask, however the evanescent decay limits the depth of focus (DOF), hence improvement in this area is desirable. We use a full vector-field finite element model of the AMOL [3] to enable a thorough exploration of the system.

Conventional near-field lithography has used the generation of plasmons on metal surfaces to improve the DOF with plasmonic reflectors [4], and to improve transmission with superlensing [Melville]. Here we incorporate plasmonic metals into the AMOL system and investigate how the system reacts, in particular how the additional reflections change the performance of the photochromic layer for lithographical situations. Simulations show that plasmonic reflectors are able to improve the DOF and confinement of light beneath the photochromic apertures. Similarly we show that a superlens is able to transmit the AMOL image and to reduce the undesirable transmission of the second wavelength. These results demonstrate the ability of AMOL to produce sub-diffraction limited exposures and show how further improvements are possible through the introduction of plasmonic layers.

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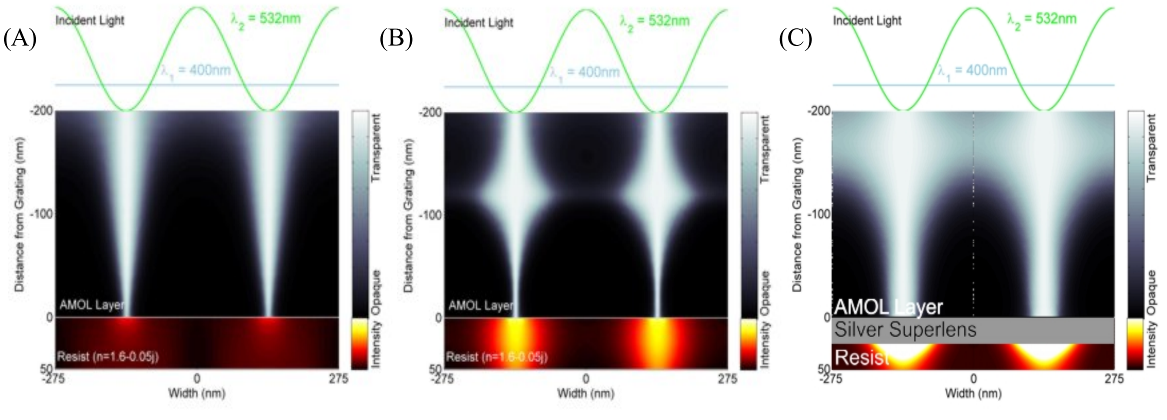

Figure 1. Schematics showing the incident waveforms, the absorbance in the photochromic layer and the intensity in the resist layer for simulations with an infinite resist (a), a plasmonic reflector (b-reflector not shown) and a silver superlens (c)