Super-resolution Optical Nanolithography using two approaches of Absorbance Modulation

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The conventional limit to the size of the smallest structure that can be fabricated using optical lithography is traditionally half the wavelength of the illuminating light[1]. Absorbance Modulation Optical Lithography (AMOL), has recently been shown to be able to successfully pattern nanoscale features beyond this diffraction limit[2]. The conventional AMOL process utilized a dual-wavelength (λ_1 – writing beam, UV and λ_2 – confining beam, visible) illumination system similar to STED microscopy [3] and thin films of photochromic molecules (the Absorbance Modulation Layer (AML)) and their reversible photo-chemical state transitions to achieve deep sub-wavelength resolution patterning[4]. Here we report on the most recent developments in AMOL.

The traditional AMOL process required the presence of a barrier layer in between the AML and the recording medium i.e. photoresist in order to protect the latter from the harsh organic solvents of the former. The first technique is a top-down barrier-layer-free method similar to conventional photolithography where the AML is formulated to be chemically compatible with the resist formulations and thereby not require the use of a barrier layer, as shown by the illustration of the sample stack in Figure 1(b). Some results are presented of isolated lines with patterning of features of line-width 80-90 nm and large area patterning with features smaller than 100 nm - Figure 1(d, e). The smallest lines resolved are equivalent to $\lambda_1/3.8$ and $\lambda_2/7.6$, respectively.

The second technique is an attempt to separate the AML from the rest of the sample stack, thereby allowing it to be reused for multiple exposures like a programmable mask. This technique involves dividing the sample stack into two parts – (a) a quartz slide with an AML and a barrier layer on top and (b) a silicon wafer with a photoresist layer. The two parts can be brought in intimate contact during the time of exposure and then separated afterward, allowing us to use the AML as a programmable, reusable and recoverable mask. So far we have been successfully able to reuse the AML multiple times.

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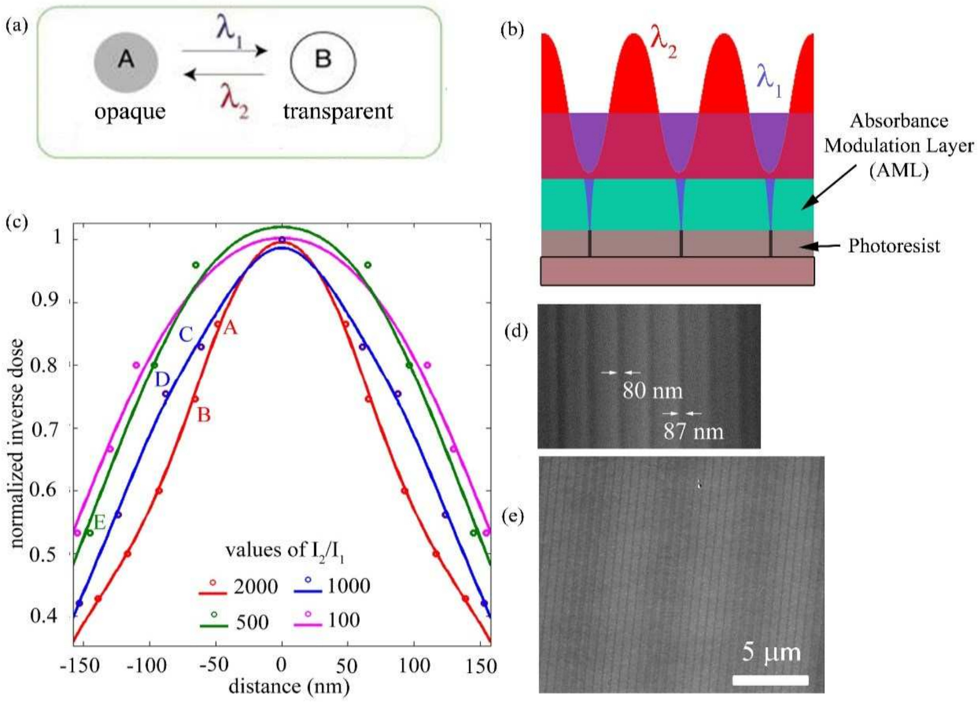

Figure 1: (a) Photo-switch-ability of the photochromic molecule used in AMOL. (b) Sample stack with photoresist as a recording medium below the layer of photochromic molecules and simultaneous exposure at two wavelengths - λ_1 – writing beam (325 nm) and λ_2 – confining beam (647 nm). The sample stack is free from the presence of any barrier layer. (c) Scaling characterization plot for the AMOL process – the line-spread function (LSF) in the photoresist scales with the ratio of the intensity of the two beams. (d) SEM image of lines with line-width around 80-90 nm. (e) SEM images of large area patterning with features below 100 nm.

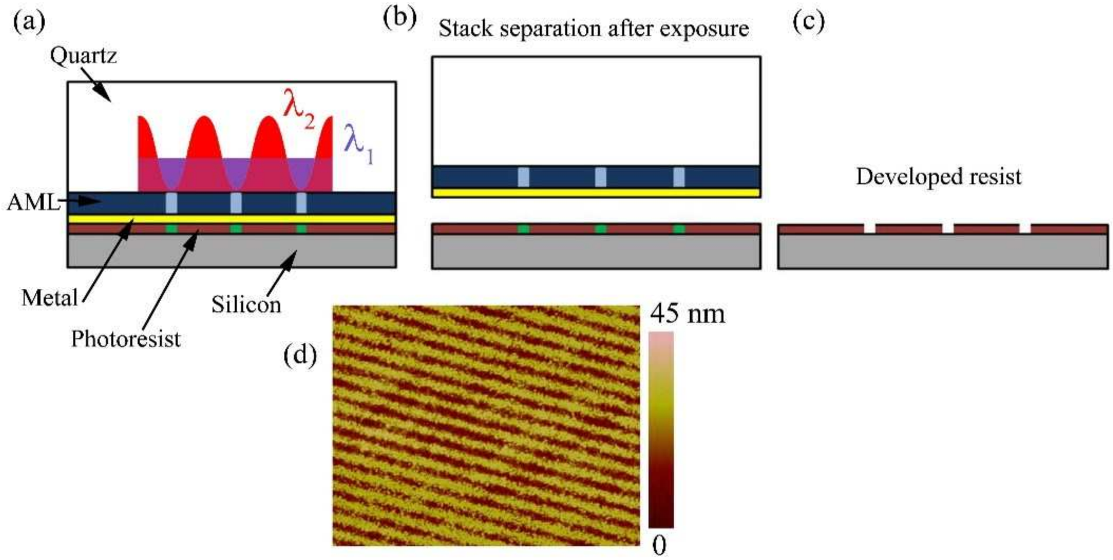

Figure 2: (a) The sample consists of two parts - the top part comprising the Quartz slide, AML and metal barrier layer and the bottom part of the photoresist spun on the silicon that is subject to exposure. (b) The two stacks can be separated after exposure and (c) the resist separately. (d) AFM images of lines fabricated in the resist of average line-width 230 nm.