EUV Lithography using Colloidal Nanoparticles

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The advancement of new light generation techniques has paved a pathway to push the resolution of nanolithography to pattern increasingly smaller feature sizes. In the recent years, EUV lithography has shown great promise in patterning sub 100 nm nanostructures [1-2]. Traditionally several top-down lithography processes have been used to obtain high resolution features but using methods such as EUV interference lithography has several challenges such as requiring precise incidence angles as well as highly specialized and expensive multi-layer mirrors to pattern nanostructures [1]. Colloidal nanosphere lithography has proven to be an effective and inexpensive near-field technique to tackle this challenge that employs self-assembled nanoparticles to create complex 2D and 3D nanostructures [3-4]. However, existing work typically ultilizes UV lasers, which has limit the pattern resolution to above 100 nm range.

In this work, we propose the use of EUV light coupled with nanosphere lithography to pattern scalable sub-100 nm feature nanostructures. In the experimental setup, a tabletop EUV source powered by a 40 fs ultrafast femtosecond 800 nm, IR laser is used [5]. The IR laser is made to pass through a glass capillary with argon gas for high harmonic generation (HHG) and output a EUV beam of 100 micron spot size. The beam is spectrally filtered to single out 30 nm wavelength EUV light and focused using multilayer mirrors onto the sample stage chamber to conduct the exposure experiment. For the experiment, a 35 nm positive tone e-beam photoresist (ZEP-520A) was spin coated on a silicon substrate, followed by transferring 200 nm polystyrene nanoparticles onto it. The sample with the assembled particles is exposed with 200 mJ/cm^2 dose of EUV light, after which the nanoparticles were removed and the photoresist was developed in an n-amyl acetate solution (ZED – N50). This exposure resulted in obtaining a nanopattern with 50 nm feature size.

The initial modeling and fabricaiton results are shown in Figure 1. The diffraction pattern below the self-assembled particles simulated using finite-difference time-domain (FDTD) is shown in Figure 1(a), which shows a complex intensity distribution. The top-view SEM of the exposed sample is shown in Figure 1(b), and agrees well with the simulated intensity profile as shown in the inset diagram. The cross-sectional simulation helps to visulaize that putting spacer layers in between the nanoparticles and photoresist will allow us obtain even denser nanopatterns. Additional experimental results with magnified SEM top-views of the beam spot are shown in Figure 2. We will present the detailed optical modeling of the EUV intensity pattern and fabrication results. This work provides a proof of concept study to pattern nanostructures by using EUV colloidal lithography for sub-100 nm features.

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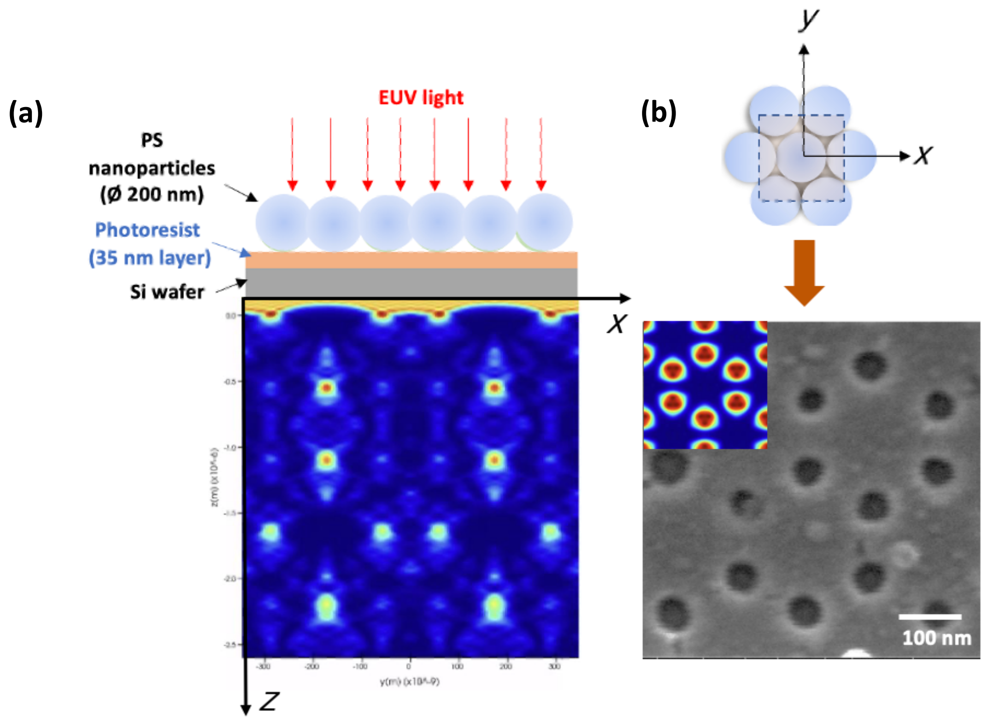

Fig. 1 (a) Simulated cross-sectional EUV intensity pattern from the nanoparticles using FDTD. (b) Top-view SEM of fabricated result and the inset shows top-view intensity profile.

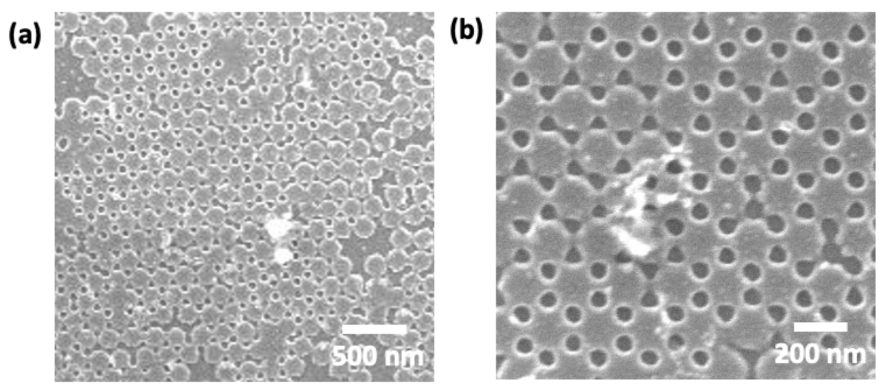

Fig. 2 Experimental top-view SEM of exposed positive tone photoresist on Si with a 200 mJ/cm^2 dose at (a) 15000x mag., (b) 77000x mag.

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