Sub-50 nm EUV Lithography using Colloidal Nanoparticles

Saurav Mohanty*, Ethan Flores, Chih-Hao Chang
Walker Department of Mechanical Engineering, The University of Texas at Austin, Austin, TX 78712, USA
**saurav@utexas.edu*

Extreme ultraviolet (EUV) lithography has been pushing the limits of optical lithography techniques to pattern sub-50 nm feature sizes and has been the key driving innovation that currently powers the semiconductor industry [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 multilayer 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 utilizes UV lasers, which has limit the pattern resolution to above 100 nm range.

In this work, we propose using colloidal nanosphere lithography coupled with an EUV light source to pattern periodic geometric patterns. The experimental setup involves 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 μm 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 120 nm positive tone e-beam photoresist (ZEP-520A) was spin coated on a silicon substrate, followed by assembly of 100 nm polystyrene nanoparticles using Langmuir-Blodgett assembly. The coated samples are then exposed using normal illumination.

Initial results have been performed and the sample with the assembled particles exposed with various dose range between 3 to 150 mJ/cm^2 of EUV light as shown in Fig. 1, characterization using scanning electron microscopy (SEM) shows that the exposure spot size varies from 75 to 100 μm as the exposure dose is increased from 3 to 150 mJ/cm^2. The nanoparticles were removed by ultra-sonicating the sample in an DI water bath, and the photoresist was developed in an n-amyl acetate solution (ZED – N50). This exposure resulted in obtaining a nanopattern with sub 50 nm feature size as shown in Fig. 2. The experimental particle assembly was modeled using FDTD simulation software (Fig. 3) to understand the light diffraction behavior caused by the 100 nm particles and it shows that complex periodic geometric patterns can be obtained on an underlying photoresist layer by varying the photoresist layer thickness in the Z direction. We will present the numerical simulation, process details, and fabrication results in more details.

---

[1] *W. Karim, Y. Ekinci, et. al., Nanoscale, 2015,**7**, 7386.*

[2] *H. S. Kim, et. al., Appl. Phys. Express, 2016, **9,** 076701.*

[3] *C.-H. Chang, L. Tian,W. R. Hesse, H. Gao, H. J. Choi, J.-G. Kim, M. Siddiqui, and G. Barbastathis, Nano Letters, 2011, **11** (6), pp 2533–2537.*

[4] *X. A Zhang, I-T. Chen and C.-H. Chang, Nanotechnology,2019, **30,** 352002*

[5] *A. Rundquist, C. G. Durfee III, Z. Chang, C. Herne, S. Backus, M. M. Murnane, and H. C. Kapteyn, (5368), Science, 1998, **280,** pp 1412–1415.*

Figures

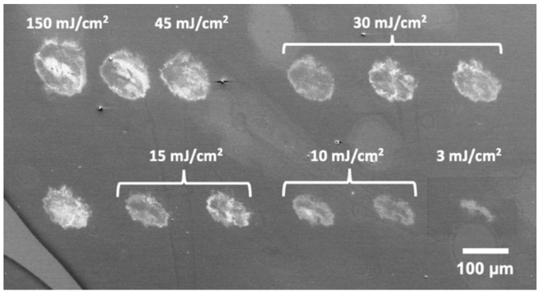

Fig.1: Dose characterization test with 100 nm polystyrene particles coated on top of ZEP 520A positive tone resist.

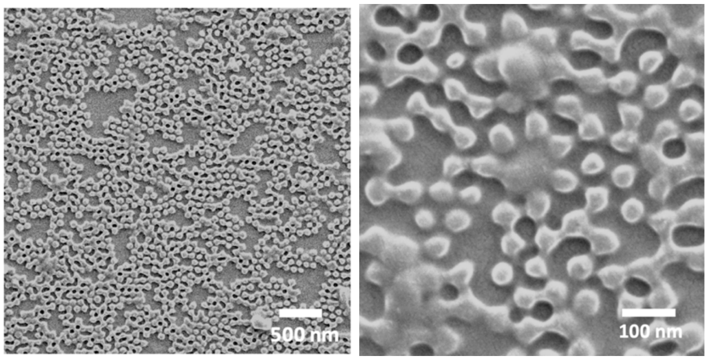

Fig.2: Experimental SEM image of developed EUV exposure pattern after removal of polystyrene nanoparticles.

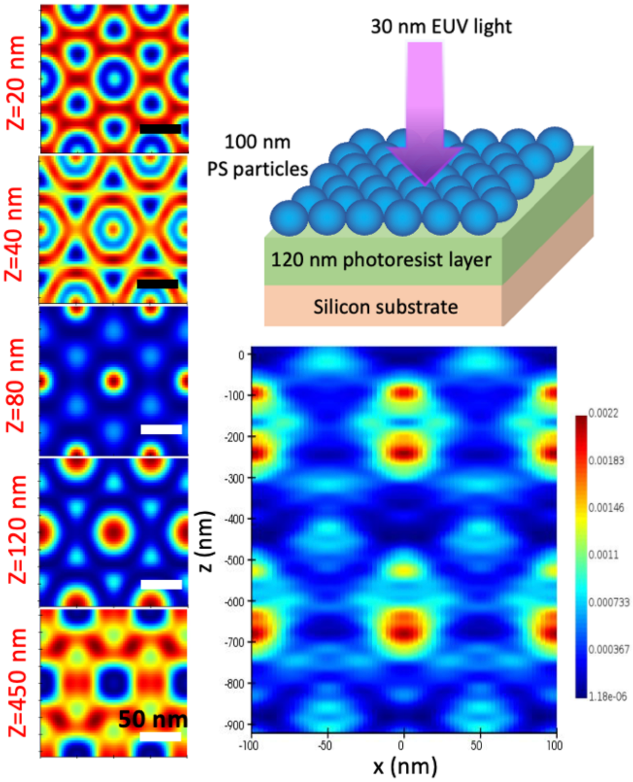

Fig 3: FDTD simulation model of proposed experiment.