Gray scale electron beam lithography for photon-nanojet based nanolens with super resolution lithography prospect

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In recent years, focusing beyond diffraction limit by nanoject effect in dielectric microspheres have been theoretically predicted as well as experimentally demonstrated[1]. Inspired by this success, we have innovated a new concept of nanolithography technique by converting microspheres into nanostructures, essential for nanojet to fulfill super resolution focusing for developing a novel nanolithography with super resolution. In this paper, we report our progress in the nanofabrication of such 3D novel nanolens based on nanoject induced super resolution focusing effects by grayscale electron beam lithography.

Figure 1 shows schematically demonstrates the concept of the lithography process using the novel photon nanojet lens (PN lens) instead of microspheres. Our finite-difference time-domains (FDTDs) simulation has proved the focusing behavior of a dielectric nanoshpere (as oppose to microsphere) with the resolution of sub diffraction limit (1/3λ-1/2λ). It is found that such kind of nanaolithography has prospects for both single layer patterning of periodical gratings (when the resist is thin enough) and 3D photonic structures when the resist is thick, as shown in figure 2. Monte Carlo simulation for charge distribution by BEAMER , TRACE & LAB was
Gray scale electron beam lithography (EBL) has been developed for the designed lens profile as templates using PMMA initially. However, this effort encountered an intrinsic problem, i.e. surface roughness after development. Then, a negative tone chemically amplified resist (CAR), UVN-30, is used. As the result, negative tone resist gives rise to much smaller surface roughness than positive. Figure 4

[1] Zengbo Wang. Optical virtual imaging at 50 nm lateral resolution with a white-light nanoscope. NATURE COMMUNICATIONS, 2011.

shows the resultant profile in 3D by a high resolution ZEISS SEM. The resist profiles are applied as templates for PN lens. To eliminate the influence by the backscattering electrons from the substrate, a underlay of 200 nm PMMA is used. Casting of PDMS onto the patterned resist profile has been carried out to form the nanolens. Other flowable polymers with higher refractive index will also be tried to replace PDMS for optimizing the photon nanojet lithography.

By summary, 3D nanolens with semi-cylindrical shape have been fabricated in PDMS by grayscale EBL, assisted by Monte Carlo method. It was demonstrated that negative tone UVN-30 is significantly better than PMMA in surface roughness. This work shows the promising step forward in developing novel nanolithography by white lights.

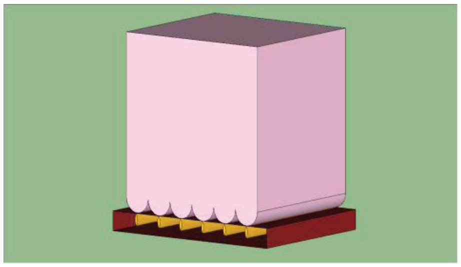

Figure 1.The scheme of optical nanolens lithography: The nanolens is on the top on the photo resist. When the incident light come, the nanojet induced focus point is able to expose the photo resist.

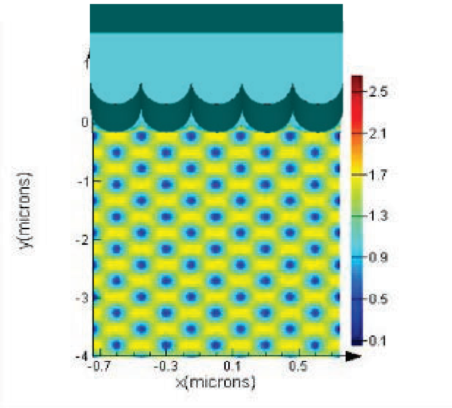

Figure 2. The simulation results of exposure process with the novel nanolens: The color bar stands for the normalized intensity of the lights. The incident wavelength is 365nm. The refractive index of optical nanolens is 2.2 and 1.45 spatially.

Figure 3. The simulation result of dose distribution of EBL with TRACE : The dose distribution is for 1.4um PMMA. After development process, the periodical nanolens is fabricated.

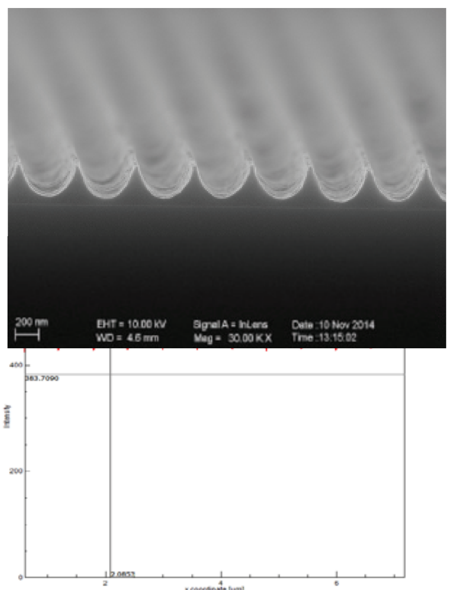

Figure 4. The SEM image of 500nm periodical nanolens: The structure is on top of the Silicon substrate, when a layer of 200nm PMMA is coated between the substrate and the UVN-30, a larger height difference is obtained.