

Metrology of Periodic 3D Nanostructures using Spectroscopic Scatterometry

Kwon Sang Lee, Kun-Chieh Chien, Barbara Groh, Michael Cullinan, and Chih-Hao Chang
*Walker Department of Mechanical Engineering, The University of Texas at Austin, Austin, TX
78712, USA*

cody_lee@utexas.edu

Periodic three-dimensional (3D) nanostructures possess unique properties and are promising for various applications in nanoscience/engineering. These properties arise from the combination of different materials and the periodic arrangement of the nanostructures. Unlike homogeneous materials, these nanostructures exhibit special dispersion behavior and can be utilized as photonic/phononic crystals. [1,2] Therefore, several techniques have been investigated to generate light intensity distributions that are periodically distributed, including interference or phase-shift lithography, which enable the patterning of 3D geometries in photoresist. In our previous works, we have demonstrated the feasibility of manufacturing 3D periodic nanostructures over a large area by using hexagonal-close-packing (HCP) nanospheres as a near-field phase mask. [3,4] However, the increasing complexity of these structures poses a challenge for inspection, which is usually carried out using cross-section scanning electron microscopy (SEM). Although this method is effective, it destroys the sample and damages the structure geometry. Other conventional methods to characterize the resulting features have been limited in its application due to inherent drawbacks: either being destructive in their nature, limited to 2D structures. [5]

In this work we demonstrate a non-destructive, high-throughput method for 3D metrology of periodic nanostructures spectroscopic scatterometry. The proposed process is based on building an optical model of the phase element to predict the intensity pattern, which can be used to predict the patterned nanostructures in the photoresist. The reflectance spectra of the structure can then be calculated and compared with the experimentally measured data. The structures with different lattice geometry and porosities will result in different reflectance spectra, allowing the geometric properties to be estimated via inverse modeling. This approach is high-throughput, non-destructive, and can be implemented in real-time for *in situ* monitoring.

Initial results in Figure 1 shows three different samples all fabricated by exposing an array of 500 nm nanospheres on top of thick positive photoresist to 325 nm wavelength light. The dosage was varied between 70 and 130 mJ/cm² to achieve low to high porosities in the resulting 3D structures in the photoresist. Figure 1(a) shows the condition of underexposure, where the light does not propagate all throughout the photoresist and thus has the lowest porosity. Figure 1(b) and (c) show the results from the photoresist exposed to higher dosage, allowing for more porosity in the photoresist. Figure 1(d) shows the case in which the photoresist has been overexposed and the 3D nanostructures have collapsed. Figure 2(a) illustrates the different spectral responses of each of the three cases, showing the distinct spectra response of the three nanostructures. The spectra response has clear correlation with the patterned 3D nanostructure, with lower porosities showing higher reflectance spectra magnitude. Also, the dips of the spectra response all happen at different wavelengths adding another factor of examination for cross referencing spectra response to porosity. Figure 2(b) summarizes the measured top diameters of the porous structures, with error bars representing two standard deviations. We will present the detailed fabrication work on fabrication and metrology of 3D nanostructures fabricated using both colloidal particles and lithographically patterned 2D phase mask. [1,6]

Figures

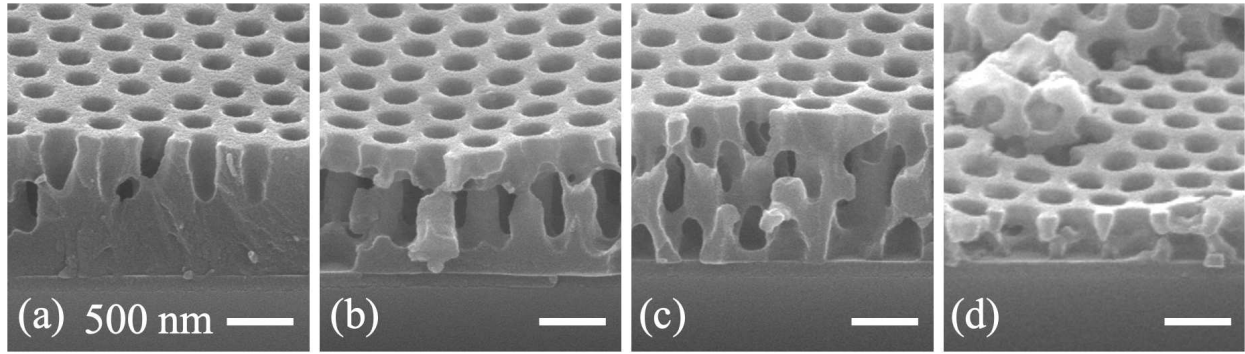


Figure 1. Top view SEM images of 500 nm period 3D nanostructures made by 325 nm wavelength colloidal phase lithography process. Doses are (a) 70 mJ/cm², (b) 90 mJ/cm², (c) 110 mJ/cm², and (d) 130 mJ/cm².

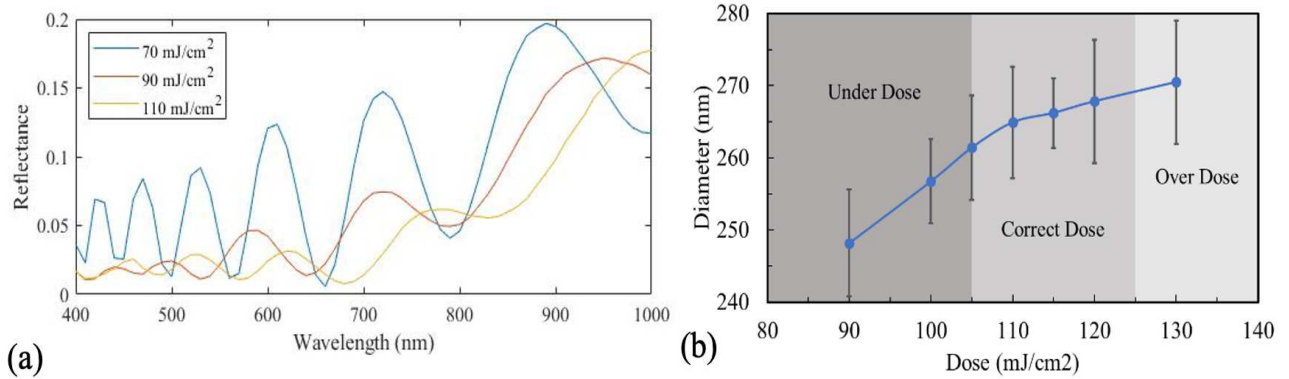


Figure 2. (a) Measured reflectance spectra from samples with exposure doses of 70~110 mJ/cm², (b) measured diameters of nanostructures using top-view SEM imaging.

References

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