Fabrication of Multilayer Photonic Reflectors using Periodic Nanolattices

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The advent of nanofabrication has opened tremendous opportunities for acoustics, photonics, and electronics industries, enabling mass manufacturing of materials having superior properties than bulk, and exhibiting unexpected effects due to scaling laws [1-2]. Presence of periodic nanostructures further amplify the effects by having ordered geometry. At the macroscale, the nanostructures provide elevated strength to weight ratios, and results in improved stiffness for a given density. With regards to thermal properties, the porous nanostructures can potentially reduce thermal conductivity. Optically, the presence of porous nanostructures can reduce the effective refractive indices to be as close as air [3]. This allows the nanostructures to serve as the low-index medium in Bragg reflectors or 1-dimensional photonic crystals, with multiple layers of high and low refractive indices to achieve perfect reflectivity over a wavelength band. The proposed research involves using multilayer nanostructures made by stacking porous nanolattice and solid layers, which can result in a highly effective dielectric mirror.

The schematic of sample fabrication for the propose nanolattice reflector is depicted in Fig. 1. In this work, self-assembly of colloidal nanospheres with 500 nm diameter is achieved by the tendency of surfaces to maintain the least surface energy. The assembled spheres are used as near-field phase shift mask and the samples are subjected to UV lithography in a 325 nm laser with 90, 100, 110 and 120 mJ/cm^2 dose exposures. The monolayer of nanospheres results in formation of periodic 3D nanostructures as is governed by Talbot effect [4]. Over this structure, a conformal coating of Al_2O_3 is deposited using atomic layer deposition (ALD) for a thickness of 20 nm within the structure. Layer height of the porous nanostructure was maintained at 120 nm, as a trade-off between strong but low aspect ratios and tall structures with high porosity, but low strength. The conformal coating allows the photoresist to act as a sacrificial template for the nanolattice [5]. This is followed by coating another layer of PFI 88 resist around 350 nm to planarize the nanolattice, followed by deposition of 80 nm thick TiO2 using electron beam evaporation to create a solid layer. The sequence of steps could be repeated with different exposure parameters and different materials to stack 3D layers to desired thickness. Finally, the structure is baked in oven at 550^oC to remove the photoresist.

The cross-sectional SEM images of 100 mJ/cm^2 dose is shown in Fig. 2a. The cross-sectional build-up of the layer is more consistent for 100 mJ/cm^2 dose than the higher doses used, indicating that 110, and 120 mJ/cm^2 could be overdose. Moreover, diameter of exposed features is larger in higher doses than the 100 mJ/cm^2. Information such as the structure depth and geometry of the periodic HCP arrangement can be inspected by the feature size captured from SEM images. Moreover, the material filling ratio, exposure condition can also be calculated. The porous and solid nanolayer stack-up is shown in Fig. 2b. The porous layer is observed to be 130 nm thick, and the solid nanolayer is 80 nm thick. The porous layer allows better thermal conduction, better reflectivity, and maintains the mechanical strength. The aim of the investigation is to fabricate a 3-layer nanostructure and characterize and investigate its properties. Moreover, post-fabrication coating on aluminium (on top) would enhance the reflectivity of the sample. The structure has significant application in photonics, to improve the reflectivity parameters.

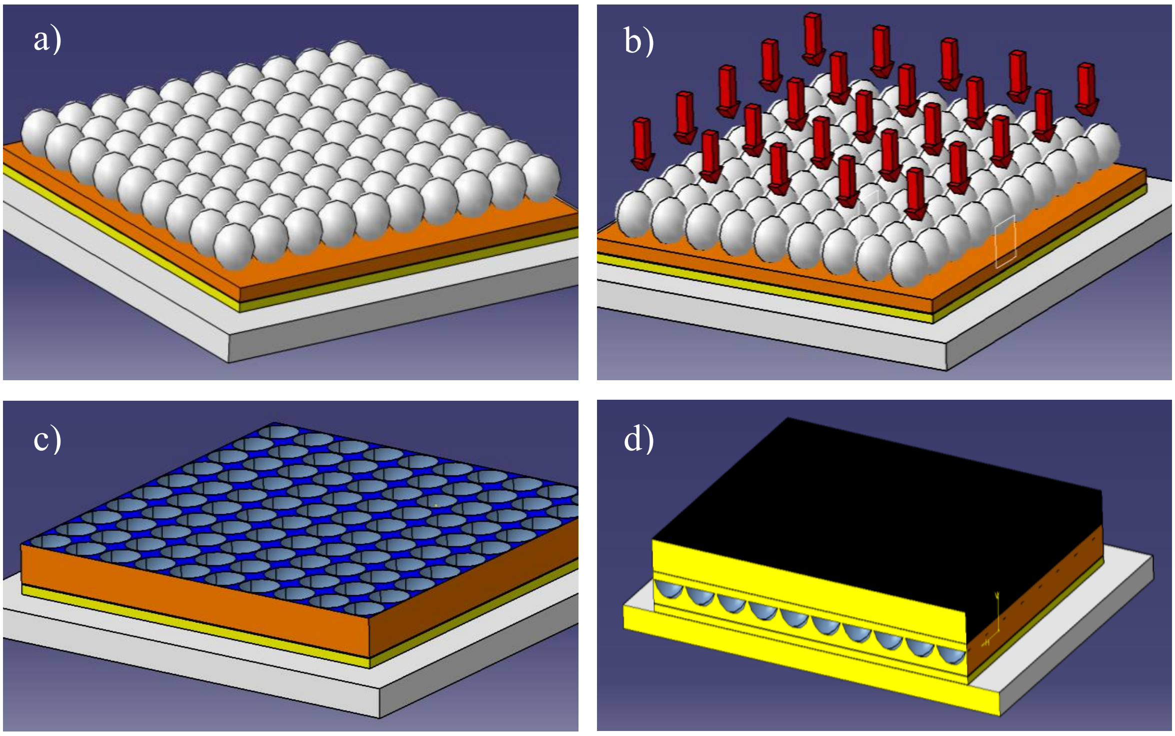

Fig. 1. Schematic of sequential process involving fabrication of porous and solid nanolayer stackup a) ARC + PR deposition + Nanosphere (500nm) coating b) 325nm UV lithography c) Development with CD-26 developer followed by ALD d) Planarization and solid layer deposition using Electron Beam Evaporation.

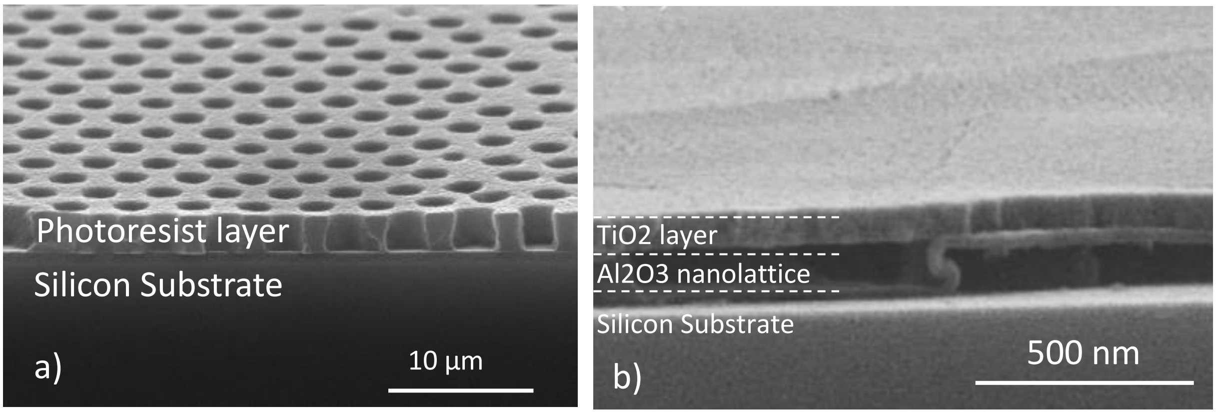

Fig. 2. SEM images of the sample with a) 130 nm thickness of PR, subjected to lithography with 325 nm UV laser at dose of 100 mJ/cm^2 cross section b) Nanolattice with Al_2O_3 thickness of 130 nm and TiO2 thickness of 80 nm deposited using Electron Beam Evaporation.

References:

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