Fabrication of Multilayer Nanolattice Reflectors with Integrated Low-Index Nanolattices

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Nanophotonics is rapidly advancing field, with significant research in integrated optics and plasmonics, driven by their promise to transform sectors like display technology, AR/VR and advanced optics **[1].** A crucial component of nanophotonic elements is Bragg reflectors, which can have near perfect reflectance over a narrow wavelength band. In these multilayer reflectors the index contrast between the high and low index layers is key, and together with other parameters including absorption coefficients and material dispersion, can influence the reflectance and scattering properties **[2].** One method to obtain high index mismatch is to use nanolattices, which can have effective index down to 1.025 while maintaining GPa range stiffness [**3**]. However, Precise control and understanding of these aspects are essential for advancing nanophotonic technologies across various fields.

In this research, we engineer multilayer reflector using nanolattices with index close to air as the basic building block. This architecture increases the index mismatch between neighbouring layers, which can enhance the overall reflectance. As shown in Figure 1, the nanolattice reflectors are patterned using a near-field phase mask consisting of hexagonally closed packed nanospheres with diameter of 500 nm over resist height of 200 nm to 600 nm for single and triple layers respectively **[4].** Subsequently, the samples are subjected to lithography with 325 nm laser with 90 mJ/cm^2 dose. After development, the samples are then subjected to atomic layer deposition (ALD) which conformally coats Al_2O_3 for 200 cycles using Trimethyl Aluminum and water as the precursors, resulting in 22 nm thick shells. Subsequently, a resist layer is coated on top of the porous alumina layer, to planarize and protect the underlying nanolattice structures. Over the planarized layer, a solid 125 nm-thick layer of TiO_2 is deposited using electron beam evaporation. This process is repeated to obtain multiple layers, after which the resist is removed from the lattice by thermal desorption.

The SEM images of the fabricated double and triple layers of alternating Al_2O_3 lattice/planar TiO_2 layers are shown in figure 2(a) and (b) respectively. Here it can be observed that the planar TiO_2 layers are supported by the nanolattices with relatively constant height. Some microcracks can also be observed in the sample due to thermal mechanical stresses. The fabricated nanolattice reflectors are characterized using spectrophotometry to obtain broadband reflectance. We also fabricated nanolattices with varying heights to design the peak of the reflectance band. The reflectance spectra of single, double, and triple pairs of 130 nm Al_2O_3 / 80 nm TiO_2 stack are shown in Figure 3(a), showing a peak at around 520 nm. The simulated reflectance for the taller reflector stacks with 200 nm Al_2O_3 / 100 nm TiO_2 height are shown in Figure 3(b), which shows a peak reflectance at around 600 nm. A second reflectance band can also be observed in the infrared, which can be attributed to the second order energy bandgap.

Simulations indicated that the reflectance can be close near 100% reflectance with relatively few layers, and the band is influenced by layer height. We intend to present comprehensive results on the fabrication of nanolattices featuring varied unit cell geometries, highlighting the challenges encountered, variations observed processing and providing detailed insights into spectrophotometry characterization.

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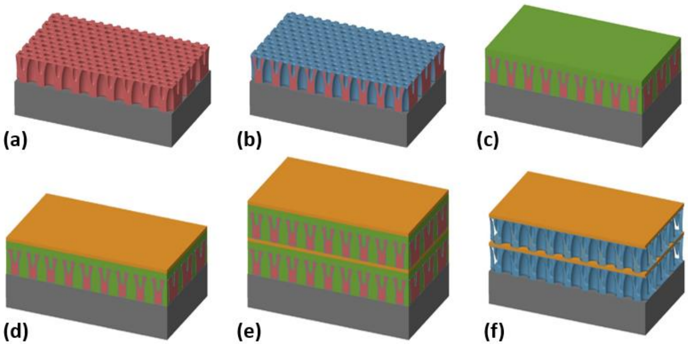

Figure 1. Fabrication process of the nanolattice reflector. (a) Pattern 3D nanostructures in photoresist and (b) deposit conformal film using ALD. (c) Spin coat polymer planarization layer and (d) deposit uniform film. (e) Repeat process for second pair and (f) remove polymer template using thermal cycle.

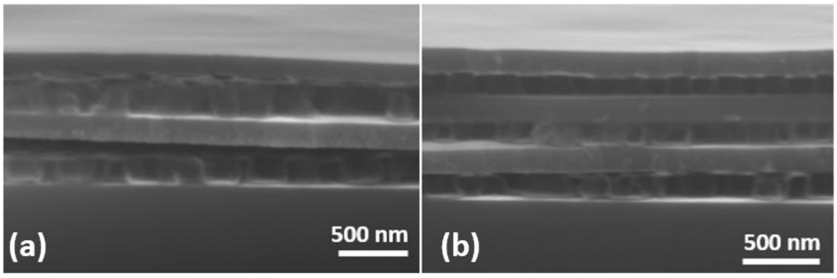

Figure 2. Cross section SEM images of (a) double and (b) triple lattices with 200 nm tall Al_2O_3 nanolattices and 125 nm tall TiO_2 solid layers.

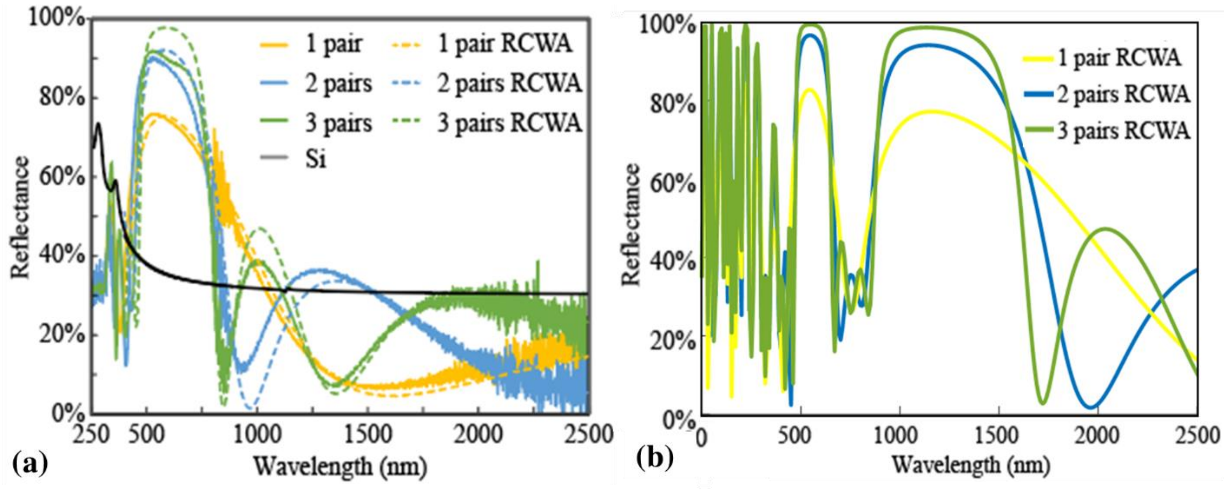

Figure 3. (a) Experimental broadband reflectance measurements of 130 nm Al_2O_3 / 80 nm TiO_2 stack with theoretical model. (b) RCWA simulations of multilayer lattices up to 2500 nm wavelength for 200 nm Al_2O_3 / 100 nm TiO_2 stack for single, double, and triple pairs.

References:

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