Large Area Plasmonic and Negative-Index Nanostructures Fabricated by Nanoimprint

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Large area, plasmonic and negative index nanostructures have wide applications in single molecule Raman sensing [1], optical antenna arrays [2], and unique guiding and controlling of light [3]. Yet the fabrication of these structures is very challenging for many fabrication methods, but well suited for nanoimprint, due to its high resolution, 3D patterning, large area and high throughput [4]. Here, we present the novel fabrications of large area metal-insulator-metal (MIM) pillar arrays (plasmonic materials) and split nanoring arrays (negative-index material) based on nanoimprint, as well as device characterization.

The imprint mold for MIM pillar arrays consists of a 2D pillar array of 160 nm diameter, 300 nm pitch, and an 4" wafer area. The mold was fabricated by using double fabrication cycles of nanoimprint and etching [5] with a 1D 300 nm grating mold (First cycle created a 1D daughter mold, and the second cycle created the pillar mold). In MIM structure fabrication, a uv-nanoimprint process with double layer resists created hole arrays in the resists (The mold imprinted the first layer resist, and RIEs transferred the patterns into the second layer resist). Then a ultra-thin Ti adhesion layer and an Au/SiO2/Au sandwich were evaporated into the resist hole arrays, and lift-off left a MIM pillar array on the substrate (Fig.1).

The measured transmission spectra of the MIM pillar array showed two dips in visible wavelength, indicating the excitations of a symmetric mode and an anti-symmetric mode of plasmons inside the two metal disks. The symmetric mode generates electric response and the anti-symmetric mode generates magnetic response to the incident light. Hence by combining these two modes, both negative permittivity and permeability can be achieved, leading to negative refractivity index.

The split-ring array, another important negative index structure, has each metallic ring broken into two pieces. Fabrication of these structures by EBL is limited to very small area and low throughput. We fabricated split-ring array by (a) nanoimprinting of large-area ring array in a resist, (b) three shadow evaporations from three oblique angles to deposit a metal into a part of ring resist profile, and (c) a lift off (Fig. 3). The ring imprint mold was fabricated from a pillar mold [6]. We fabricated Au split ring array with 400 nm diameter and < 100nm gap over 2 inch sq-in area (Fig. 4). The split-ring array is expected to have magnetic resonance modes, that would generate negative magnetic permeability. For the dimension of our devices, the negative index at mid-infrared wavelength range is expected.

Clearly, nanoimprint is a powerful tool for large area and low cost fabrication of plasmonic and negative index materials.

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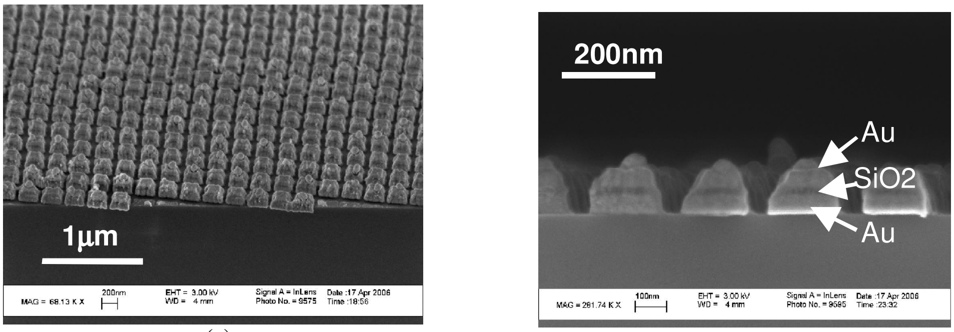


(a) (b)

Fig.1. SEM of (a) a MIM (Au/SiO2/Au) pillar array fabricated by imprint, metal deposition and liftoff, and (b) the cross-section of the array (200 nm period, 60 nm thick gold and 24nm SiO2)

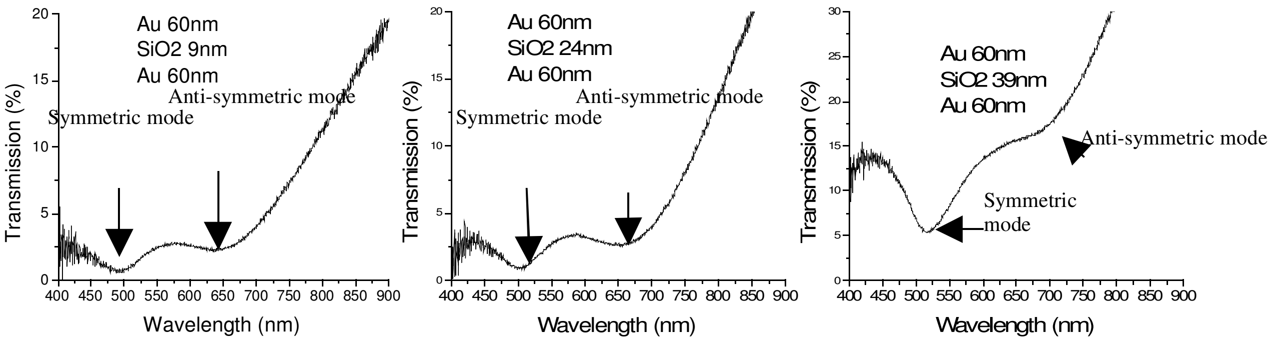


Fig.2. Measured transmission of the MIM pillar array with different SiO2 thickness. The peaks is due to an symmetric and an anti-symmetric mode, respectively.

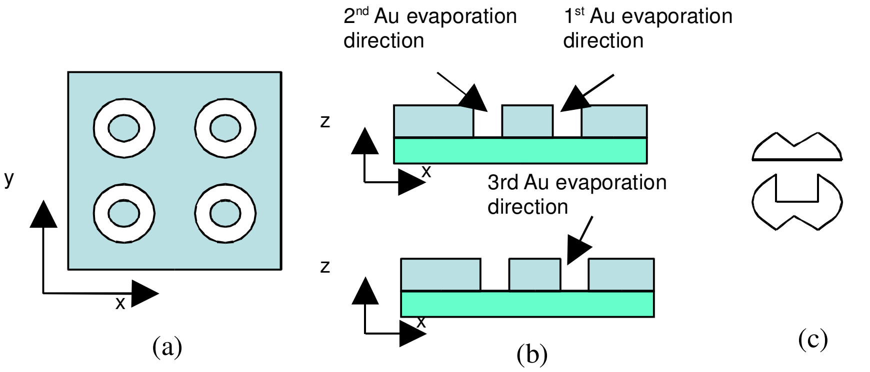
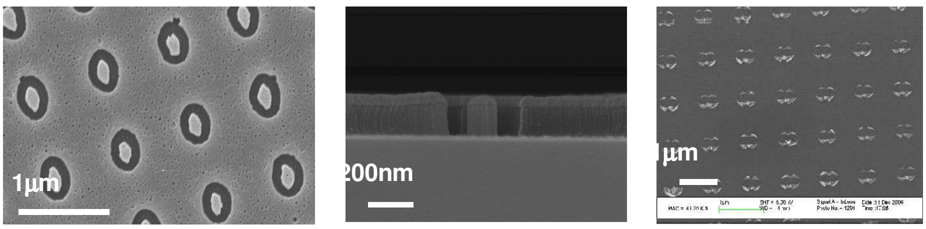


Fig.3. A schematic of (a) ring trenches in resist, (b) shadow evaporation of the metal three times from different angles, and (c) top view of the metal patterns after liftoff.



(a) (b) (c)

Fig. 4. SEM of (a) a resist after imprinting (the average diameter of rings is 400nm), (b) the cross-section of the imprinted and transferred resist (trench is 200 nm deep and 100 nm wide) , and (c) Au split-ring array (400 nm average diameter and split gap is smaller than 100nm) after three shadow evaporations of Au and a liftoff.