Three Layer Plasmonic Biosensor with High Sensitivity

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Optical biosensors based on localized surface plasmon resonance (LSPR) spectroscopy show advantages of highly sensitive, label free, fast, and small sample volume. These LSPR sensors are useful to detect DNA hybridization. To increase the sensitivity of the LSPR biosensors, nanoparticles with different shapes such as dots, holes, rings, squares, cubes, asymmetrical patterns, and quasi three dimensional (3D) nanostructures have been investigated [1, 2]. Most of these studies focus on one or two plasmonic layers with limited sensitivity and plasmon modes. Here we proposed a novel three layer plasmonic nanostructure composed of Au nanosquares as the top layer, Au asymmetrical nanostructure as the middle layer, and Au asymmetric nanoholes as the bottom layer. This three layer plasmonic nanostructure allows the hybrid plasmonic coupling of the symmetrical and asymmetrical Au layers. Enhanced electromagnetic (EM) field intensity is observed around the two asymmetrical layers as well as the top symmetric layer, as shown in Fig. 1. The results show that the EM field intensity of the three layer plasmonic nanostructure is higher than the 2D or quasi 3D plasmonic nanostructure, which could be useful as a high sensitivity LSPR biosensor.

Figure 2 shows the three layer nanostructure with different dry etching time to remove the residual layer after using reversal nanoimprint to stack the nanopillars on top of the bottom pillar array. As shown in Fig. 2(a), a thin residual layer of ~50 nm was found after 30 s of dry etching in 20/2 sccm O_2/SF_6, 20 mTorr, and 100W rf power. Figure 2(b) shows the three layer nanostructure without residual layer after etching for 45 s. The top SU-8 pillars are 200 nm wide with 535 nm pitch and 400 nm thick, while the bottom SU-8 pillars are 280 nm wide with 535 nm pitch and 500 nm thick.

The refractive index (RI) sensitivity of three layer plasmonic nanostructure was measured by immersing the sensors in certified RI liquids with RI of 1.305, 1.404, and 1.504. As shown in Fig. 3, the three layer plasmonic nanostructure shown three resonance peaks at 584, 818, and 1049 nm in liquid with RI of 1.305. All the resonance peaks and valleys were red-shifted in liquid with increased RI. High sensitivity of 346 and 397 nm/RIU are achieved for resonant peaks at 584 and 818 nm.

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[1] S. Zhu, H. Li, M. Yang, and S. W. Pang, Nanotechnology 27, 295101 (2016).
[2] C. Wu, A. B. Khanikaev, R. Adato, N. Arju, A. A. Yanik, H. Altug, and G. Shevets, Nat. Mater. 11, 69 (2012).

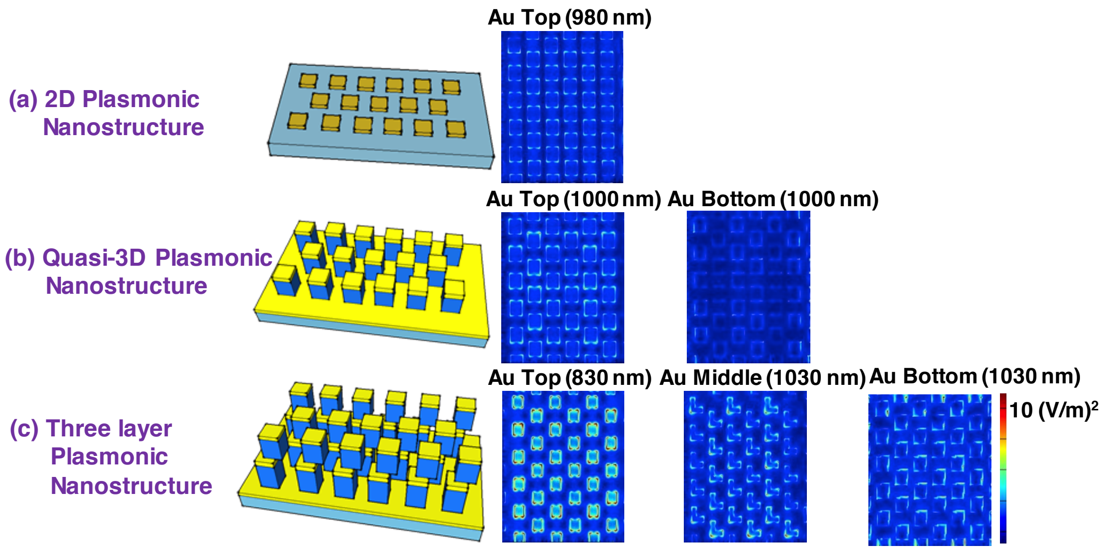

Figure 1: Simulated electromagnetic field intensity distributions for (a) 2D plasmonic nanostructure, (b) quasi-3D plasmonic nanostructure, and (c) three layer plasmonic nanostructure.

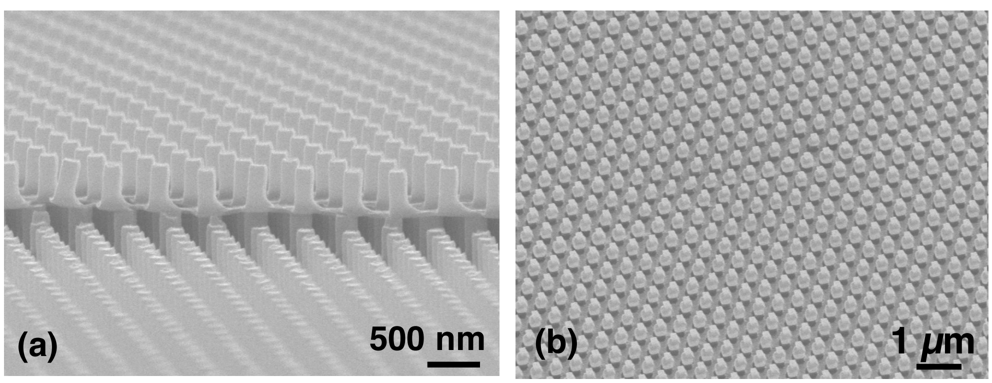

Figure 2: Micrographs of stacked three layer nanostructure with different dry etching time. (a) After 30 s dry etching with ~50 nm residual layer. (b) After 45 s dry etching with no residual layer.

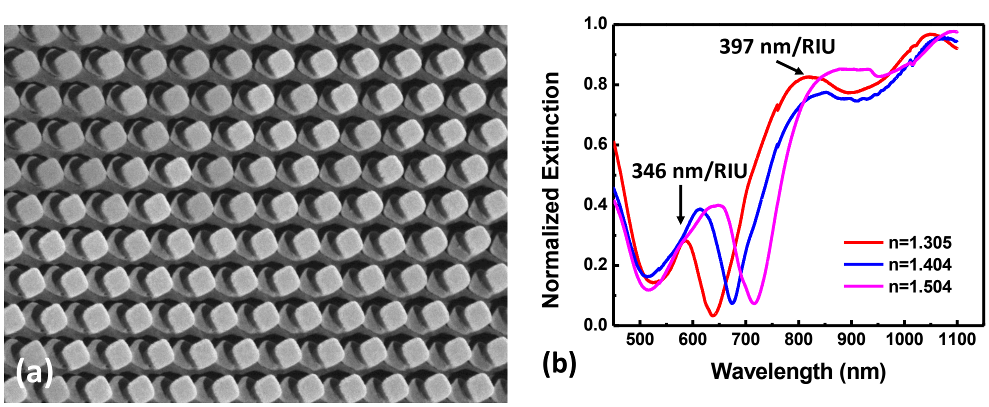

Figure 3: (a) Micrograph of three layer plasmonic nanostructure. (b) Normalized extinction spectra in liquid with different refractive index.