Sub-wavelength gold nano pillars for high sensitive LSPR sensors

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Sub-wavelength metallic nanoparticles as local surface plasmonic resonators (LSPRs) have been investigated substantially because of its unique functionality as bio/gas-sensors. However, its low specific surface area limits its sensitivity. To overcome this problem, high aspect ratio pillar arrays with large resonating space are needed. So far, the reported techniques are using nano hole array generated in anodic aluminum oxide (AAO) film as templates to form nano gold pillars by electroplating. Unfortunately, there existing numerous disadvantages in association with this technique including poor periodicity, limit of height, need of residual Al_2O_3 film as a mechanical support, impurity and uncontrollability of fabrication process, etc. These limitations lead to complicity in the reflectance/transmission spectra[1].

In this work, we have developed a nanofabrication method using electron beam lithography (EBL) combined with electroplating to form ultra-high aspect ratio gold pillars with strictly controllable sub-wavelength period, as shown in figure 1. Periodical Au pillars with 2 μm in height, 256 nm in diameter (8/1 aspect ratio) and 400 nm in period have been achieved. Both theoretical simulations by FDTD method and optical measurements have been carried out. Figure 2 demonstrates simulated standing-wave of local surface plasmonic excitations existing in the resonant cavity (air space between the pillars), generated by the dipoles on the top edge of two adjacent pillars. The height of pillars are the characteristic length for selecting the resonant wavelength to be either reflected (1/4λ rule) or absorbed (1/2λ rule) as shown in figure 3a. The resonating peaks can be tuned by the substance in the cavity as the basic principle of high sensitivity sensing when the cavity is enlarged as in this work. Figure 3b shows the initial measurement results from nano pillars with a height of 960 nm, diameter as 220 nm, and period as 400 nm. Both simulation and measured reflectance spectra indicate the LSPRs are strongly related to the geometry of the gold nano pillars as well as the dielectric index in the cavity, showing promising prospect for high sensitivity sensors.

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[1] David PL, Jeong MM, Alexander VK, Vladimir MS, and Alexander W. Gold nanorod arrays as plasmonic cavity resonators. *ACS Nano*, Vol.2, 2569-2576, 2008.

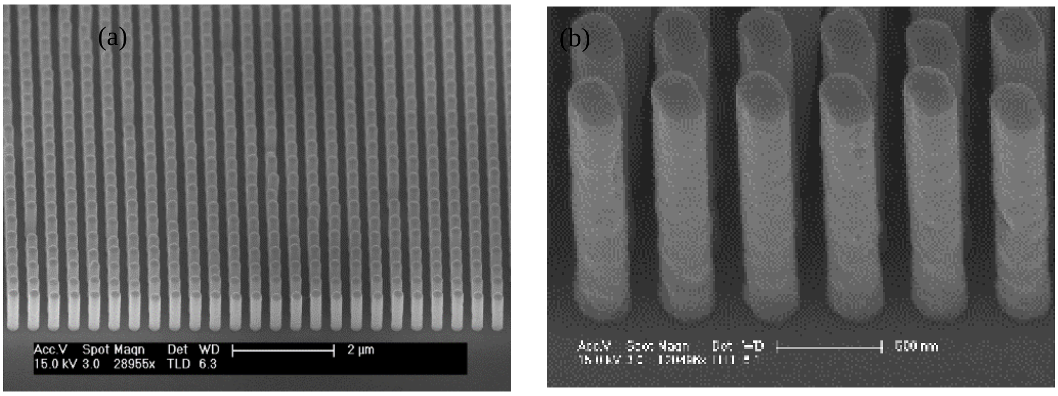

Figure 1. SEM image of gold pillar arrays. (a) Height is 960 nm, diameter is 220 nm (5/1 aspect ratio). The scale bar is 2 µm; (b) Height is 1940 nm, diameter is 260 nm (8/1 aspect ratio).The scale bar is 500 nm.

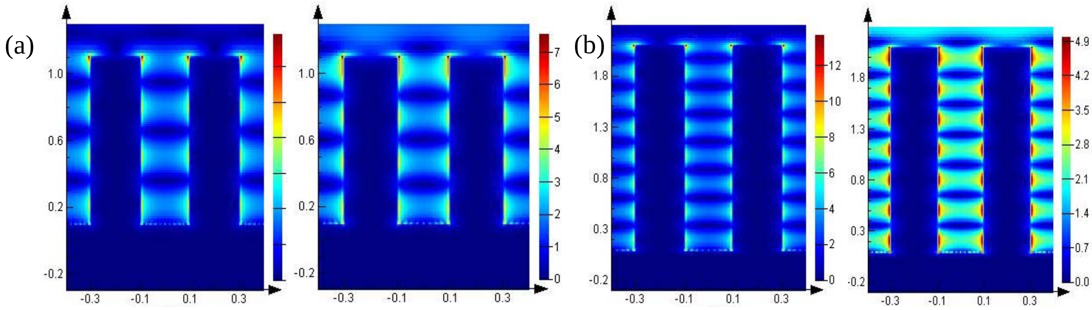

Figure 2. Cross sectional view of electric field distribution of gold pillars at different response frequency with height respectively as (a) 1 µm and (b) 2 µm. The pitch is 400 nm, and diameter 200 nm.

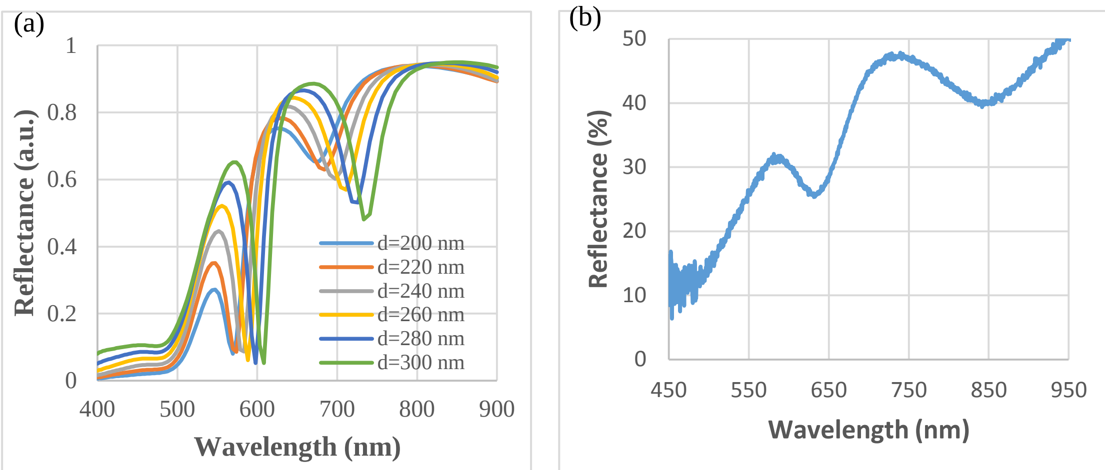

Figure 3. (a) Reflectance Spectra for gold nano pillars with changing diameters by FDTD simulation. Obvious redshift of absorption peaks can be seen with increasing diameter. (b) Measured spectra of gold pillar arrays with the height as 960 nm, diameter as 220 nm, period 400 nm. The measured reflectance spectra qualitatively agree with the measured behavior.