Animating optical materials for a sensor device

Pei-Yu Chung, Tzung-Hua Lin, Gregory Schulz, Christopher Batich, Peng Jiang.
Materials Science and Engineering Department, University of Florida, Gainesville, FL 32608
Obstetrics and Gynecology, University of Florida, Gainesville, FL 32608
Department of Chemical Engineering, University of Florida, Gainesville, FL 32608

Statement of Purpose: Nanoscale substrates have generated considerable recent research interest in the field of biomedical engineering. As these substrates enable extraordinary optcial phenomena, there have been numerous studies that demonstrated their efficacy for optical biosensing devices. Nanoscale metallic gratings are like animating optical materials as the color changes vividly by alternating an incident angle. This effect is induced while gratings separate an incident polychromatic wave into its spectral components. For developing a cost-effective methodology, we have developed a scalable bottom-up technique for generating wafer-sized periodic gold nanopyramids with nanoscale tips as an efficient surface-enhanced Raman scattering substrate. Here we demonstrate that the templated nanopyramids can also be utilized as sensitive surface plasmon resonance (SPR) sensors for chemical and biological sensing.

Methods: Periodic Au nanopyramids were fabricated by a simple templating technology using spin-coated monolayer colloidal crystals as structural templates. A sandwich cell, consisting of a gold nanopyramid array, a 2 mm thick polydimethylsiloxane (Sylgard 184) spacer, and a glass microslide, was used to evaluate the reflection from the nanopyramids when the cell was filled with glycerol solutions of different refractive indices. A high-resolution spectrometer (HR4000, Ocean Optics) with a tungsten halogen light source (LS-1) and a reflection probe (R600–7) was used for the optical measurements. The angle of incidence was controlled at 45° by using a RPH-1 probe holder. For biosensing experiment, the Au nanopyramid array was treated with Protein A to enhance the conjugation of rabbit IgG on Au nanopyramids. 5 mg/ml of Protein A (MP Biomedicals) was put on a clean Au nanopyramid array sample and incubated overnight at 4 °C. After incubation, the nanopyramid array was rinsed three times with phosphate buffered saline (PBS) buffer to wash away unadsorbed Protein A and then incubated with 10 μg/ml of rabbit polyclonal to alcohol dehydrogenase (abcam) overnight at 4 °C. The corresponding normalized reflection spectrum due to the adsorption of anti-alcohol dehydrogenase with a peak wavelength of 595.9 nm. 40 ng/mL of alcohol dehydrogenase (MP Biomedicals) in PBS was then added on the array and incubated for 1 h at room temperature, followed by three times rinsing with PBS buffer for removing unbound residue.

Results: Periodic Au nanopyramids were fabricated by a simple templating technology using spin-coated monolayer colloidal crystals as structural templates. Figure. 1 shows tilted scanning electron microscope (SEM) images of an array of gold nanopyramids templated from 320 nm silica spheres. The long-range hexagonal ordering of nanopyramids can be clearly seen. Figure 1 reveals the sharp tips and the smoothness of the nanopyramids. In the reflection spectra obtained from glycerol solutions of different refractive indices, a redshift in the maximum reflection wavelength was observed as the solution refractive index increases. The sensitivity of the nanopyramid array was evaluated to be 239 nm per refractive index unit (nm/RIU) and is favorably comparable to other grating coupler-based SPR sensors. The biosensing experiment shows that a peak wavelength was shifted from 595.9 to 602.3 nm when alcohol dehydrogenase was added.

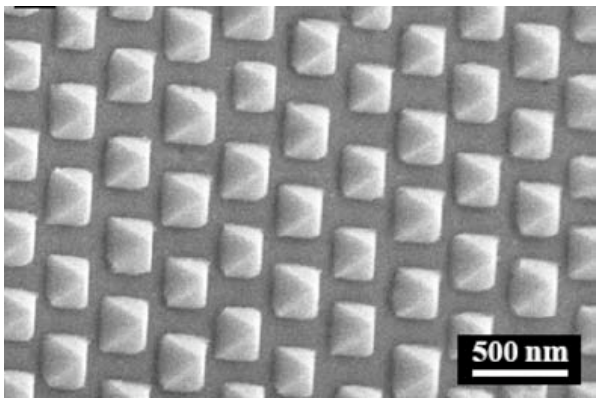

Figure 1. SEM images of a templated Au nanopyramid array

Conclusions: In summary, we have successfully fabricated a gold nanopyramid array by using a low-cost templating method. The technique preserves the uniformity of the sharp nanopyramid with reproducible features, and thus suggests a platform for high quality array fabrication for high-throughput sensing applications. We used alcohol dehydrogenase and anti-alcohol hydrogenase as a model system to demonstrate the functionality of the arrays in analytical bioassay performing a real-time, high sensitivity, label-free, portable and quantitative detection.