High-Throughput Fabrication of High-Aspect-Ratio Metal Nanostructures for Biosensing Applications

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Plasmonic biosensing has emerged as a non-invasive and label-free method of accurate detection of low-concentration analytes[1]. The detection mechanism of these sensors is based on shifts of very sensitive resonance peaks of metal nanostructures due to changes in the optical properties of the surrounding medium. In the last years, many geometries have been proposed for sensing applications but there are limit number of them that are produced with high throughput and can provide high sensitivity at the same time. Using e-beam lithography it has been demonstrated that high-aspect-ratio metal structures provide high sensitivities, which is attributed to their large surface-to-volume ratios[2]. We report on using interference lithography[3] at soft X-ray wavelengths for efficient patterning of photoresists over large areas and fabricating high-aspect-ratio (HAR) metal nanostructures for biosensing applications.

In our lithography approach ~1µm thick photoresist is spincoated and exposed by overlapping beams that are diffracted from a broadband grating mask. We use synchrotron radiation, which is tuned depending on the photoresist chemical composition. While not more than ~100-nm-thick resist could be exposed at conventional EUV (13.5 nm), by using wavelengths close to the atomic absorption edges of the composing resist atoms, where photoresists have their minimum absorption, thick layers could be successfully exposed. We have tested patterning nanostructures on Hydrogen silsesquioxane (HSQ) at 2.5 nm and Polymethylmethacrylate (PMMA) at 4.5 nm, which accordingly correspond to the oxygen and carbon edges (Figure 1). After patterning the photoresists, metal nanostructures are grown using electroplating to a height limited by the photoresist thickness and mechanical stability of the structures (Figure 2).

We have focused our work on fabricating gold nanopillars and have studied their spectral-response dependence on the pillar geometry (diameter and height) as well as array periodicity. Our method is a novel technique beyond the conventional LIGA technology, in that much longer wavelength are used and also sub-100 nm structures are easily produced with high resolution and reproducibility.

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[1] J. N. Anker, *et al*., Nature Mat. **7**, 443 (2008).
[2] B. Päivänranta, *et al*., ACS Nano **22**, 6374 (2011).
[3] B. Päivänranta, *et al*., Nanotechnology. **22**, 375302 (2011).

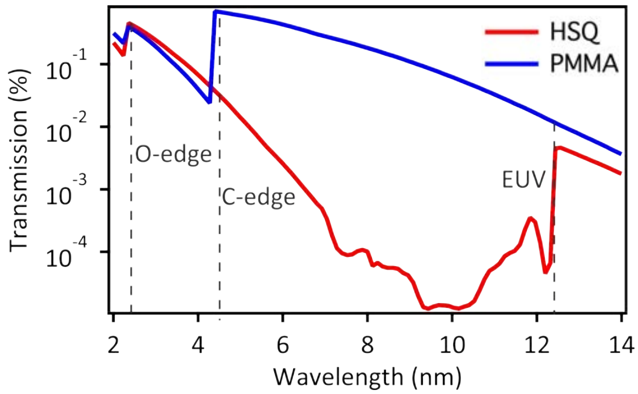

Figure 1: Transmittance Spectra of HSQ and PMMA. The corresponding atomic edges of carbon (C) and oxygen (O) as well as the EUV wavelengths are indicated by dashed lines.

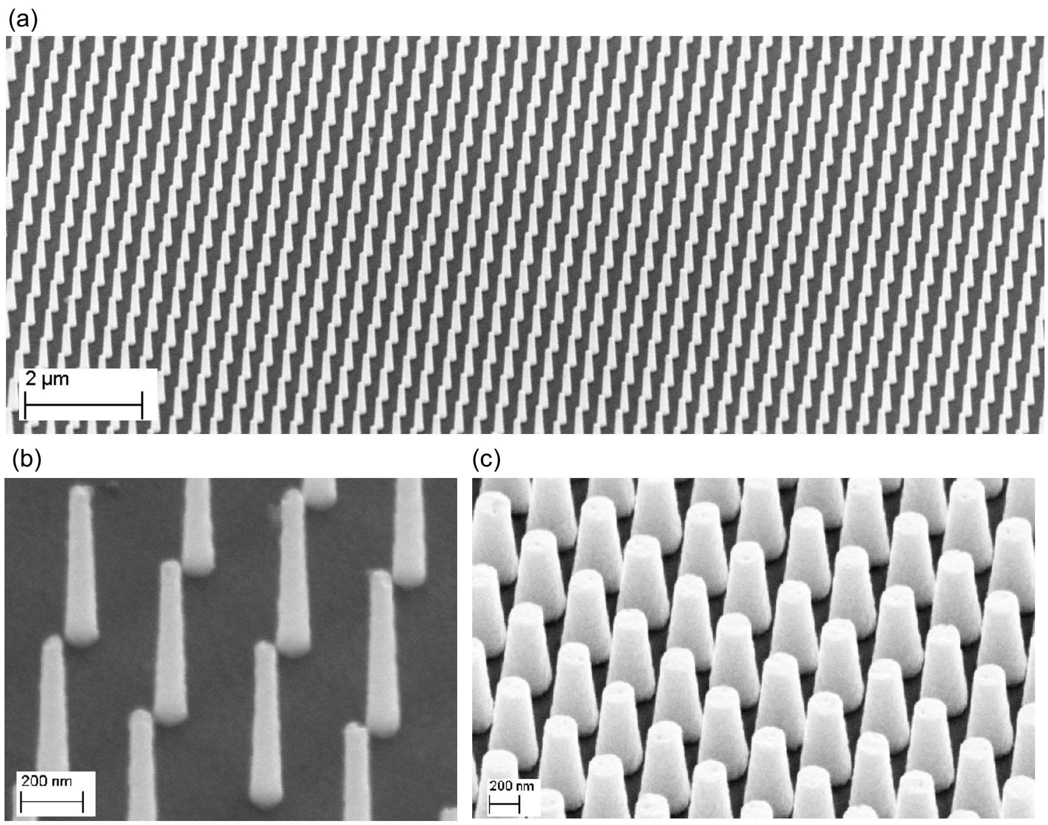

Figure 2: High-Aspect-Ratio Nanostructures: (a) Fabrication of gold nanostructures arrays over large areas. (b) Nanostructures with aspect ratio of ~10 with high mechanical stability. (c) Fabrication of dense arrays of separate nanopillars.