Tilted lithography and pattern transfer for the fabrication of asymmetric 3D plasmonic nanostructures

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In recent years plasmonics has attracted a lot of attention as plasmonic nanostructures facilitate the confinement and enhancement of the electric field of an electromagnetic wave.[1] These effects can be used for surface-enhanced Raman spectroscopy[2] and single molecule detection.[3] Nanocones are well suited for these applications as they have sharp tips at which the electric field of an incoming electromagnetic wave is increased and confined.[4]

It can however be shown that the tips of rotationally symmetric cones cannot be excited under perpendicular incidence of collimated light, while either tilted illumination or breaking the symmetry of nanocones, introducing components along the direction of the exciting electric field, supports the transformation of transversal far-field radiation to a high electric field enhancement at the tips.[5] Simulations reveal that slanted nanocones satisfy this requirement under perpendicular illumination.

Electron beam lithography (EBL) is a common tool for the fabrication of planar 2D metallic nanostructures. In order to expand this to 3D structures typically multiple exposures and pattern transfers are required.[6]

Here, we introduce 3D patterning of a polymethyl methacrylate (PMMA) resist layer via tilted EBL. Tilting the sample during the exposure[7] combined with the evaporation of metals under an angle (see Figure 1) enables the fabrication of slanted nanocones (see Figure 2) and other asymmetric 3D metallic nanostructures. Working distance correction enables the exposure of sufficiently large areas involving stage moves.

A second, alternative fabrication process that was developed consists in the transfer of nano-masks into a gold layer via argon ion milling under a tilting angle (see Figure 1), resulting in slanted nanostructures (see Figure 3).

Process details, SEM images, numerical simulations and measurements of the optical properties of the asymmetric plasmonic gold nanocones will be presented.

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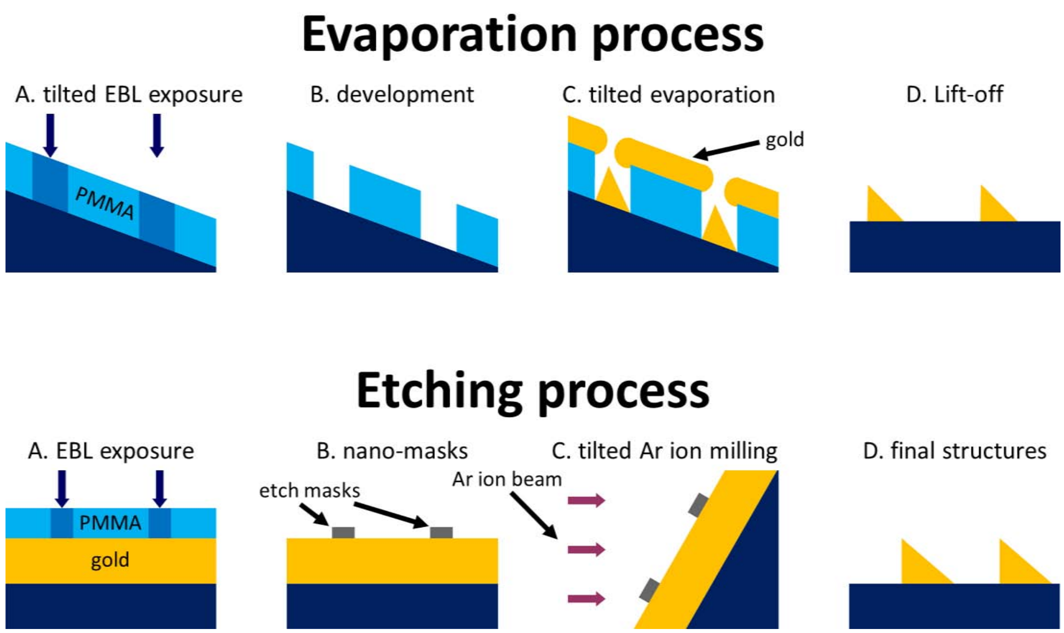

Figure 1: Process flows for the presented fabrication processes.

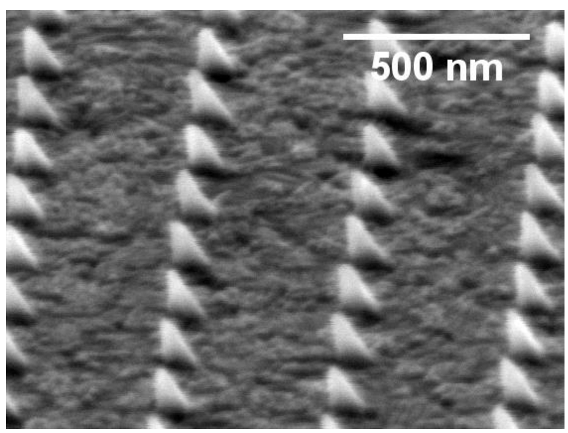

Figure 2: SEM image (side view, viewing angle 75°) of an array of evaporated slanted gold nanocones.

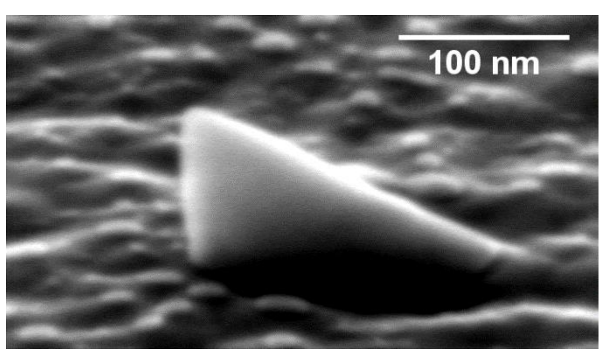

Figure 3: SEM image (side view, viewing angle 75°) of an etched slanted gold nanocone.