Nanoscale engineering of 3D plasmonic nanostructures using focused helium ion beam milling

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With the development of the helium ion microscope new paths in nanoscale imaging and nanofabrication were opened up. The high resolution, sub-nm beam diameter allows for the milling of e.g. sub-5 nm slits.[1] It further enables the precise geometric manipulation of metallic nanostructures and therefore the precise tuning of their plasmonic properties.[2,3] Plasmonic nanostructures are optical antennas with similar properties as their macroscopic counterparts, but with an operating wavelength in the optical spectrum.[4] Far-field and near-field characteristics of such optical antennas can be accurately customized. Garcia-Etxarri et al. theoretically introduced the indented nanocone, consisting of a nanocone with a concentric sub-10 nm slit around the apex. It enhances the electric near-field at the tip of the nanostructure compared to a pure cone due to Fano-like resonances.[5] The fabrication of the proposed nanostructure is nearly impossible with standard nanofabrication techniques. Figure 1 shows one of the first indented nanocones fabricated by focused helium ion beam milling (HeFIB).

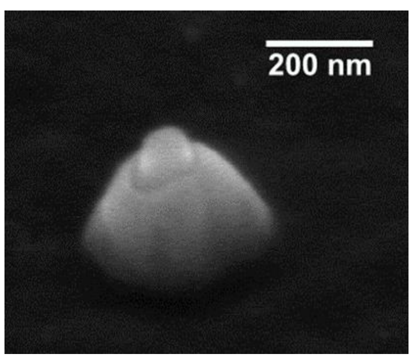

Figure 1: Indented cone with a concentric sub-10 nm slit around the apex.

Here, we show the geometric manipulation of pre-patterned nanostructures by HeFIB. For this purpose gold nanocones were fabricated via an etch mask transfer into a gold layer.[6] The desired patterns were then carved into these structures with the helium ion beam. We investigate the optical properties of the pre-patterned and nano-engineered nanostructures using dark-field scattering spectroscopy and back-focal-plane imaging. This enables us to draw conclusions on the antenna characteristics. The process details, SEM images, numerical simulations and the optical properties of various engineered 3D plasmonic nanostructures will be presented.

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