Sub-10-nm Three-Dimensional Plasmonic Probes fabricated using a Helium Ion Microscope

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Near-field scanning optical microscopy (NSOM) probes have been used to characterize in real time the chemical, physical and biochemical properties of materials with nanometer scale resolution [1]. The high sensitivity and resolution that can be achieved with NSOM probes relies on sub-wavelength confinement of the electric field. In recent years, improvements in nanofabrication capabilities have increased patterning resolution enabling new types of NSOM probes. Plasmonic performance increases exponentially as critical dimensions become smaller (ideally sub-10 nm). Such high resolutions require cutting-edge instruments with superior precision and control. Helium Ion Microscopes (HIM) are regarded as one of the most advanced and flexible nanofabrication tools with sub-5-nm patterning accuracy and the capability of direct writing onto a variety of materials [2,3]. Here we report the use of HIM to pattern three-dimensional (3D) NSOM tips on an Atomic Force Microscopy (AFM) probe with sub-10-nm resolution. The first geometry is a Campanile tip [4] that has a 7-nm plasmonic defect at the apex. The pyramidal AFM probe is uniformly coated with 100 nm of gold and a square aperture is milled by gallium focused ion beam (FIB) on the backside to allow coupling of light into the pyramid. On the front, two sides of the pyramid are milled by Ga-FIB up to the proximity of the apex, where high-precision milling is completed using the He-ion beam (Figure 1-a). An even more challenging geometry, namely a Pinwheel antenna, was fabricated by removing gold to leave four slices that run along the sides to the apex of the pyramid, where they form a double-gapped probe (Fig. 1-b) [5]. Simulations show that this probe can couple more light and provide higher field enhancement than the Campanile probe. Preliminary NSOM measurements of these structures are reported. These results confirm the capabilities of HIM to fabricate innovative 3D NSOM probes with unprecedented performance for use in materials science and characterization.

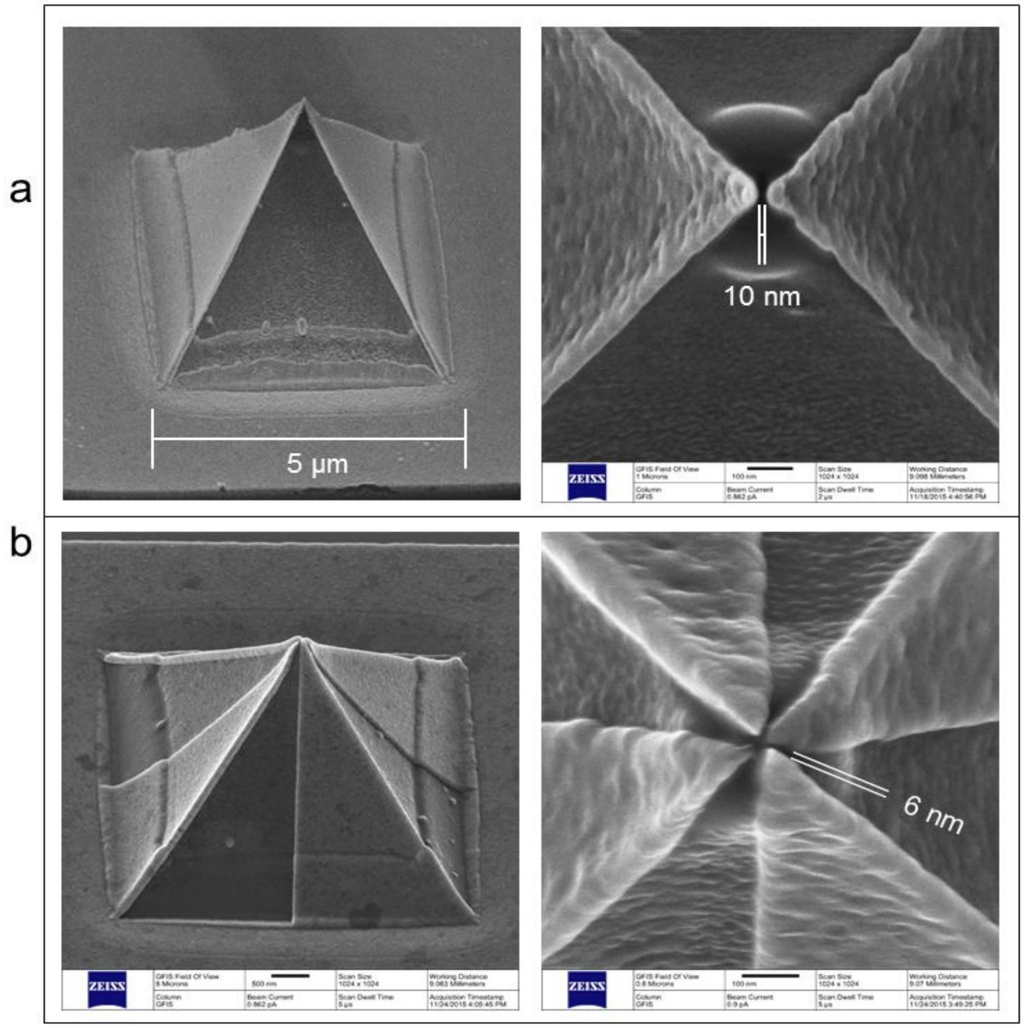

Figure 1 – HIM and SEM images of the Campanile probe (a) and a Pinwheel antenna (b) after milling.

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