FIB fabrication of metallic nanostructures on end-faces of cleaved optical fibers for chemical sensing applications

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Focused Ion Beam (FIB) fabrication of fiber optic sensors, mainly chemical and biological sensors, which are based on plasmonics-active nanostructures formed on the cleaved tips of the optical fibers is reported. The metallic nanostructures fabricated included nanoparticles, nanorods, and nanoholes in optically thick metallic films. The sensing mechanism in these fiber optic sensors is based on detecting shifts in localized plasmon resonances (LSPRs) of metallic nanostructures and surface plasmon resonances (SPR) associated with nanoholes in optically thick metallic films, when the refractive index of the medium surrounding the metallic nanostructures and nanoholes is changed [1-4]. These sensors can be employed for the detection of chemical and biological agents in air as well as liquid media surrounding the sensors. The metallic nanostructures were formed on the cleaved end-face of multimode, 4-mode, and single mode optical fibers. Metallic nanoparticles, nanorods, and nanopillars were formed on the tip or surface of the optical fiber by depositing a 30-150 nm layer of a metallic (gold or silver) film on the cleaved tip of the fiber and subsequently employing focused ion beam (FIB) milling to pattern out the metallic nanoparticles and nanopillars from the film. Separately, ordered arrays of nanoholes were formed in optically thick (100-240 nm) metallic films by employing FIB milling. Employing FIB allowed formation of nanostructures such that the plasmon resonances associated with the nanostructures could be engineered and precisely controlled by controlling the nanostructure size and shape. Multi-step FIB fabrication procedures were developed to form the nanostructures of complex geometries on tips of optical fibers. Formation of periodic arrays of nanoholes, of controlled sizes and shapes, provides a means of engineering plasmon resonance related peaks associated with extraordinary transmission of light through the array of nanoholes in the metallic films. A Hitachi FB2100 Focused Ion Beam system was used to fabricate the arrays of nanoapertures and other nanostructures such as nanopillars, nanorods, and nanoparticles. A special sample holder was designed and implemented which allowed optical fibers of one meter length to be loaded into the FIB for sensor fabrication. Beam currents and accelerating voltages of 0.01 nA and 40 keV were typically used.

References

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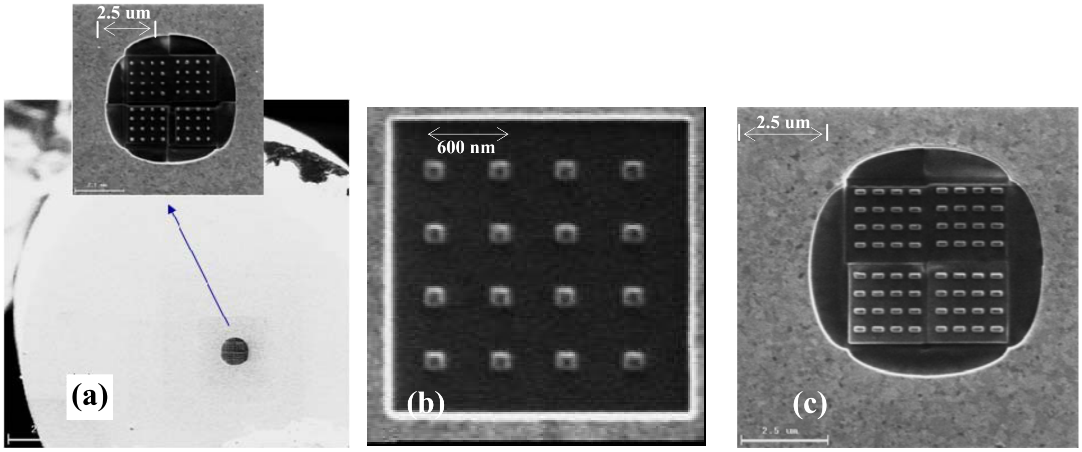

Figure 1. SEM micrograph of (a) A 8 by 8 square nanoparticle array, FIB fabricated at the tip of a 50 nm gold coated 4-mode optical fiber, (b) A set of 4 by 4 square Au nanopillars, and (c) An array of 8 by 8 Au nanorods fabricated using FIB.

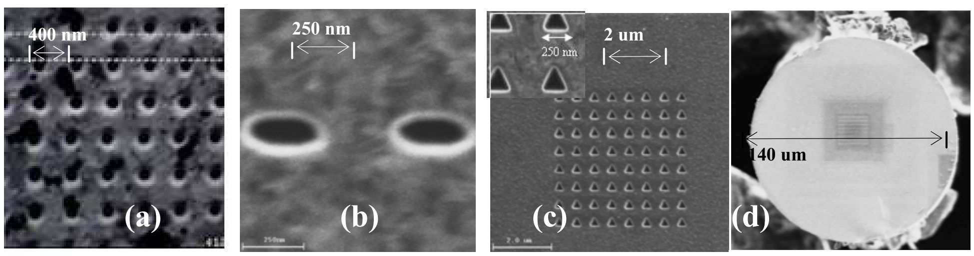

Figure 2. SEM micrographs showing 180 nm gold films having periodic arrays of nanoapertures on the cleaved end-faces of multimode optical fibers. The nanoapertures have different geometries: (a) Circular, (b) Elliptical, (c) and Triangular; fabricated on the cleaved tip of a one meter long optical fiber (d).

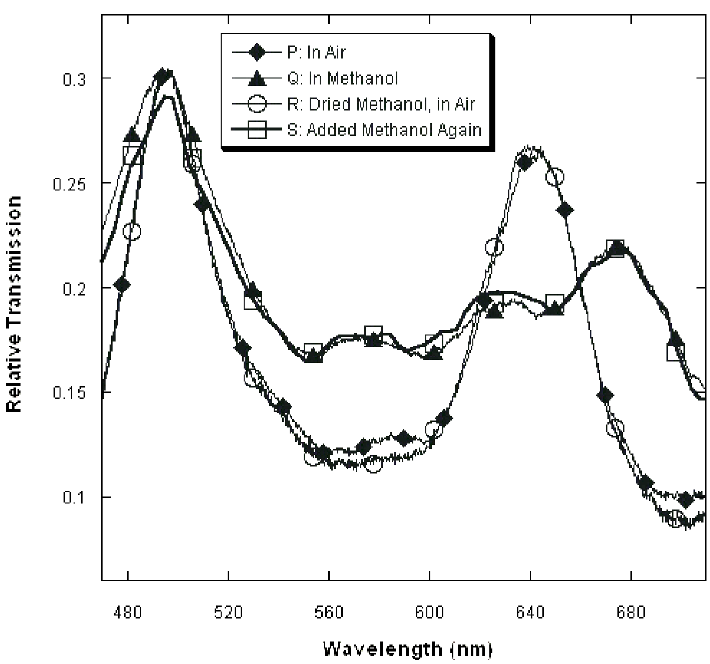

Figure 3. Transmission spectra of a 230 nm gold film having a 24 by 24 square nanohole array on the tip of a multimode fiber. The transmission spectrum was evaluated in the wavelength range 460-720 nm upon changing the medium surrounding the fiber tip from (P) Air, (Q) Methanol, (R) Air again after drying Methanol, and (S) Methanol added again to the sensor chamber. The spacing between the holes was 600 nm