Nanomenhirs for Surface-based Biosensing of Lipid Structures

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Transmembrane proteins constitute more than 50% of the world's current pharmaceutical drug targets. These proteins, which are located in the outer membrane of cells, are very sensitive to their external environment, with a tendency to denature upon contact with solid surfaces and hence cannot be studied on conventional protein arrays.[1] Solid supported lipid bilayers (SLBs) present a substrate-based cell-membrane-like format to study these transmembrane proteins. In order to provide the relatively large transmembrane proteins with sufficient space, the underlying solid substrate should be structured. Sensing the function of transmembrane proteins embedded within lipid structures can then be achieved through the use of nanoplasmonic sensing elements.

This contribution describes the fabrication of a new type of surface-based nanoplasmonic biosensor which can be used in conjunction with the study of transmembrane proteins within lipid structures and the transport of material through them in ambient conditions, whose sensing elements are cone-like Au structures, dubbed "nanomenhirs"[2] (see Figure 1). Briefly, silicon nitride was deposited via plasma enhanced chemical vapor deposition and patterned via random sequential adsorption particle assembly with particle diameters ranging between 40 and 500 nm. The high aspect ratio nanopores were etched via reactive ion etching using Cr as an etch mask. The Au nanomenhirs were deposited within the nanopores by metal evaporation. The nanomenhirs displayed multiple resonance modes. Each mode corresponded to the localization of an evanescent field to a different position on the nanomenhir, such that each mode reacted independently to changes in its local refractive index within the respective evanescent field as evidenced by both theoretical simulations (see Figure 2) and experimental data of the bulk refractive index sensitivity of the nanomenhirs (see Figure 3). This allowed the simultaneous sensing of events occurring at different parts of the sensing structure.

References
[1] E. Reimhult and K. Kumar. TIBTECH **26**(2): 82-89. (2008)
[2] K. Kumar et al., European patent application EP10013193.7, priority date 01.10.2010.

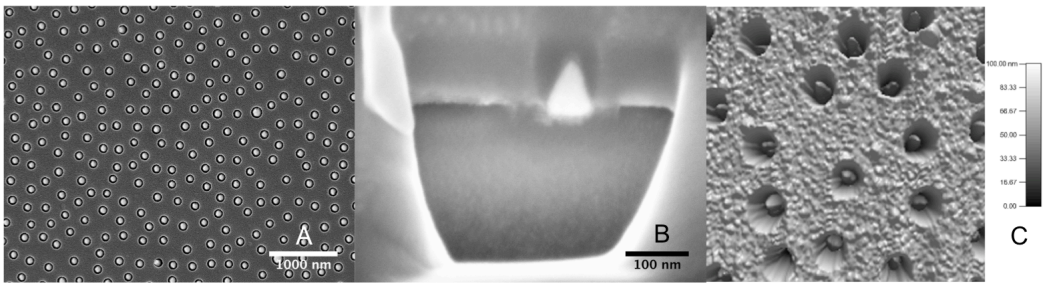

Figure 1: Nanomenhirs embedded within silicon nitride: A – Array of nanomenhirs embedded within silicon nitride nanopores. B – Structure of a single nanomenhir exposed via focused ion beam and imaged by SEM. C – Atomic force microscopy image of the nanomenhirs showing that the nanomenhirs are completely embedded within the nanopores.

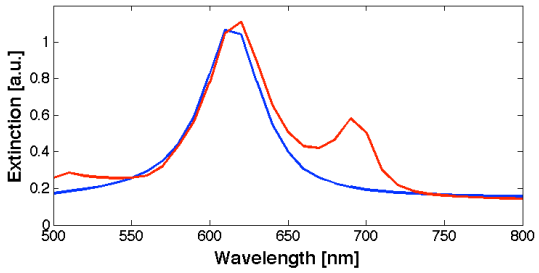

Figure 2: Simulation results of transmission spectra of nanomenhirs in water: Blue plot - extinction spectrum of sample that is orthogonally illuminated with a peak extinction at ~ 615 nm. Red plot - extinction spectrum of sample that is obliquely illuminated with two peak extinctions; one at 615 nm and one at 690 nm.

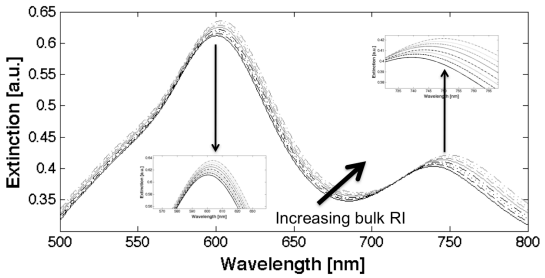

Figure 3: Bulk calibration transmission spectra of nanomenhirs in water/glycerol mixtures obliquely illuminated with p-polarized light: The 8 spectra refer to glycerol-water mixtures (0, 5, 10, 15, 20, 25, 30, 35 wt% glycerol in water). Two peaks that redshift upon increasing concentrations of glycerol are observed at around 605 nm and 740 nm respectively.