A NOVEL PLATFORM FOR HIGHLY SENSITIVE DETECTION OF MOLECULAR INTERACTIONS BASED ON OPTICAL FIBER META-TIPS

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We report on a novel biosensing platform, based on the integration of a plasmonic metasurface on the tip of a single-mode optical fiber, able to detect biomolecular interactions with very high sensitivity.

Keywords: Optical fiber biosensors

1. Introduction

Recently, within the emerging framework of the "Lab-on-Fiber" technology [1], we successfully demonstrated the integration of phase-gradient plasmonic metasurfaces on the tip of an optical fiber, giving the birth to the first "Optical Fiber Meta-Tips (OFMTs)" [2, 3].
OFMTs were realized by FIB milling inhomogeneous arrays of rectangular aperture nano-antennas (each one rotated by ±45 degrees in the plane of the fiber tip) in thin Au layer previously deposited on the fiber end-face (Fig. 1).

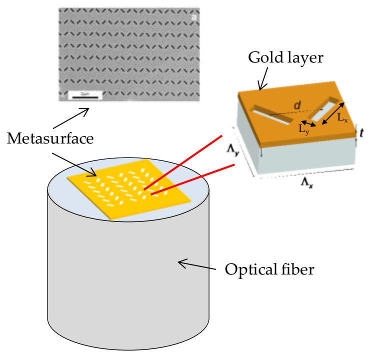

Fig. 1 Schematic representation of the OFMT-based biosensing platform

As a proof of concept, the designed plasmonic OFMTs were able to impress, to the normally impinging beam, a linear phase (and constant amplitude) profile, so as to steer the output beam in desired directions by an arbitrary deflection angle. It was also shown that OFMTs deflecting the output beam by 90° are able to efficiently couple normally incident light to surface waves, and exhibit a greater enhancement of the electric field at the meta-tip surface with respect to the corresponding gradient-free structure (consisting of a periodic pattern of the same nano-antennas but equally rotated), thus leading to an improved surface sensitivity.
In this contribution, we report on the first demonstration of an OFMT-based biosensor capable of detecting biomolecular interactions with very high sensitivity. Specifically, using the well-acknowledged biotin–streptavidin pair as a benchmark, we demonstrate the capability of a properly designed OFMT probe to detect very low concentrations of streptavidin in running buffer solutions (Fig. 2) with a sensitivity of ~15pm/(ng/ml) and a limit of detection of the order of a few ng/ml.

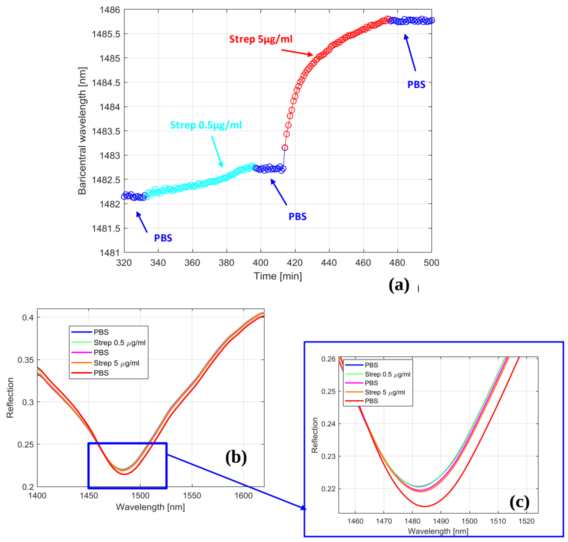

Fig. 2 (a) OFMT probe sensorgram reporting the baricentral wavelength of its resonance spectrum during a biotin-streptavidin binding experiment carried out in phosphate buffer solutions (PBS) with streptavidin concentrations of 0.5μg/ml and 5μg/ml; (b, c) reflectance spectra of the OFMT probe in the steady-state levels.

In order to assess the beneficial effect of the phase-gradient also on the biological sensing performances, the same experiments were also conducted using the corresponding gradient-free plasmonic benchmark. Notably, the sensitivity obtained with the OFMT probe resulted two orders of magnitude higher with respect to the gradient-free counterpart, thus confirming the excellent OFMTs potentialities for biological sensing applications.

References

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