Design and characterization of plasmonic nanostructures on silicon waveguides for sensing

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Abstract

Plasmonics and silicon photonics are two high-impact research topics. Plasmonics studies the interaction between light and subwavelength metallic nanostructures, opening the way towards light manipulation at the nanoscale. Plasmonic nanostructures display many interesting properties when illuminated with visible or NIR radiation. For instance, they can strongly confine electric and magnetic fields via localized surface plasmon resonances (LSPR) in deep subwavelength regions close to the metal surface [1]. This feature can be used to build highly sensitive plasmonic nanoresonators to tiny variations in their surroundings and very useful in sensing. It would be highly desirable to use such resonators on silicon waveguides, since they could be used for massive multiplexed biosensing in silicon photonics chips, enabling low-cost mass-manufacturing of biosensors.

In this work, we present and demonstrate experimentally a plasmonics-on-silicon biosensor based on an array five gold nanodipoles on a 500 x 250 nm^2 silicon waveguide supporting the propagation of the fundamental TE mode (Fig. 1). An exhaustive study about the variation and influence of parameters is performed by using CST Microwave Studio in order to achieve steep LSPR in the wavelength regime from 1260 to 1630 nm. We got a deep transmission dip when the nanodipoles are ellipsoidal-shaped with long axis (d_1=205 nm) parallel to the electric field and short axis (d_2=80 nm) parallel to the propagation direction of the guided wave, being both the gap and metal thickness equal to 30 nm. Figure 2 shows a numerical simulation, where the transmission dip is clearly seen. When applying a liquid with index 1.33 on top of the nanostructure, we get a strong red-shift of the response, resulting in a sensitivity of 520 nm/RIU and a figure of merit of 288.89 1/RIU. Figure 3 shows a SEM image of a fabricated sample. Preliminary results show a huge displacement of the dip when a liquid is deposited in the top of the fabricated sample.

This work opens new perspectives in the field of parallel simultaneous access to label-free biosensing arrays, where plasmonic nanostructures exhibit unprecedented values of sensitivity [2]. It would allow the development of on-chip multiplexed LSPR sensors with submicron size for highly-sensitive detection of multiple analytes in real-time.

References

[1] M. Lorente-Crespo et al., Nano Lett. 13 (6), (2013) 2654-2661.
[2] A. A. Yanik et al., Proc. Natl. Acad. USA 108, (2011) 11784-11789.

Figures

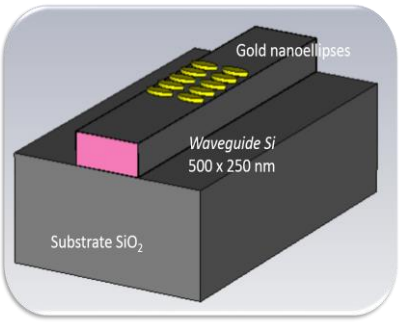

Fig1. Plasmonics-on-silicon biosensor.

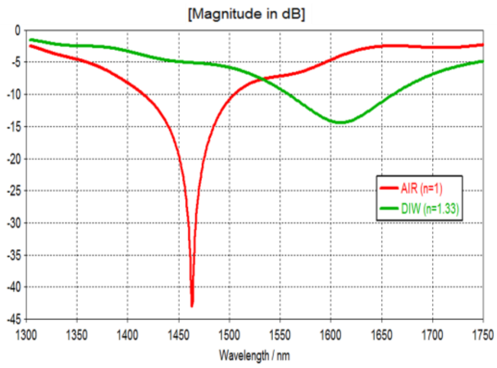

Fig2. Normalized power transmission spectrum.

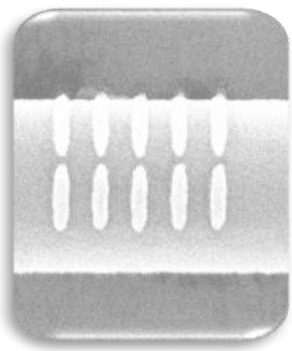

Fig3. Image SEM (Scanning Electron Microscopy) of a fabricated sample.