Compact Integrated Optical Sensors based on a Si_3N_4 Grated Waveguide Optical Cavity

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A grated waveguide (GWG), which is a waveguide with a finite-length grated section, acts as an optical resonator, showing sharp fringes in the transmission spectrum near the stop-band edges of the grating. These oscillations are due to Fabry-Perot resonances of Bloch modes propagating in the cavity defined by the grated section [1]. Any small structural changes in the environment of the GWG, which disturb the evanescent field of the GWG resonant modes, will lead to a shift of its transmission spectrum. Such an effect can be exploited for sensing applications, such as the detection of a bulk refractive index change [2] or nanodisplacements of a cantilever suspended above the GWG [3]. Here we present 3 applications: (1) a concentration sensor, based on the bulk index change of the GWG top cladding; (2) label-free protein sensing (PepN enzyme - the major Suc-LLVY-AMC-hydrolyzing enzyme in *Escherichia coli*), where the spectral shift of the GWG response is due to the antibody-antigen interaction, leading to growth of an ad-layer on it; and (3) gas sensing, where the GWG detects stress-induced deflections of a doubly-clamped microcantilever (microbridge) with a Pd top layer due to H_2 gas absorption by the Pd receptor layer.

Gratings were defined on Si_3N_4 waveguides using laser interference lithography as described in Ref. [3]. Set-ups for each sensing application will be described in detail during the conference. The cross-section of each device is shown as an inset in the corresponding graph in Fig. 1.

To demonstrate (1) concentration sensing, we filled a cuvette on the surface of the sensor with a phosphate buffered saline solution of 1 wt% (PBS1x). The evaporation of water from the open cuvette leads to a continuous change of concentration, and hence of the bulk index, which can be deduced from the measured spectral shift of the sensor (Fig. 1a). The results show that changes of the refractive index down to 2×10^{-5} RIU, and concentration changes down to 0.01 wt% can be resolved, which is comparable with the resolution of ultrasonic sensors [4].

For (2) protein sensing (Fig. 1b), it was found that the shift of a spectral peak, $\Delta\lambda_p$, in response to the antibody-antigen binding reaction changes exponentially with time t according to $\Delta\lambda_p(t) = C\,(1-e^{-t/\tau})$, where C = 342 pm and τ = 770 s. The reaction saturates after ~35 minutes. The total shift was approximately 342 pm, corresponding to the growth of an ad-layer of ~2 nm.

The sensitivity of the microbridge device for (3) gas sensing was rather low due to the relatively large gap g of ~700 nm between the bridge and the GWG (see inset in Fig. 1c). During the H_2 absorption process, the shift $\Delta\lambda_p$ depends almost linearly on time, which can be partly explained by noting that the effect of the initially rapid change of the gap size, g, is compensated by lower values of $\partial\lambda_p/\partial g$ at larger gap size (Fig. 1c, left-hand side). The H_2 desorption takes place at approximately half the rate of the absorption process, and full desorption was not achieved during the monitoring period of the experiment (Fig. 1c, right-hand side).

In conclusion, we have demonstrated the great potential of a Si_3N_4 grated waveguide optical cavity as compact integrated optical sensors for concentration detection, label-free protein sensing, and gas sensing.

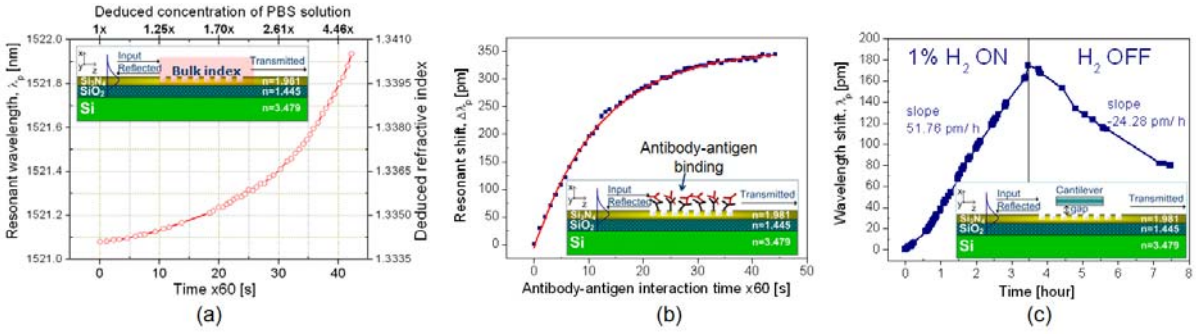

Fig.1. Performance of devices for **(a)** measurement of salt concentration, **(b)** label-free protein sensing, and **(c)** gas sensing. Cross-sections of the sensor structures are shown in the respective insets.

References

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