Si_3N_4 Grated Waveguide Optical Cavity based Sensors for Bulk-index Concentration, Label-free Protein, and Mechano-Optical Gas Sensing

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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]. Small changes in the environment of the GWG, which disturb the evanescent field of the GWG resonant modes, lead to a shift of its transmission spectrum. This effect can be exploited for sensing applications by 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 GWG spectral shift is due to the antibody-antigen interaction and 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 [3]. 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). Evaporation of water from the open cuvette continuously changes the concentration, hence the bulk index, which is measured as a spectral shift of the sensor (Fig. 1a). 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 spectral shift of a peak, $\Delta\lambda_p$, in response to the antibody-antigen binding reaction changes with time t approximately according to $\Delta\lambda_p(t) = C\,(1-e^{-t/\tau})$, where $C = 342$ pm and $\tau = 770$ 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 a micro-bridge 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 is partly due to the initially rapid change of the gap size, g, being 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 (Fig. 1c, right-hand side).

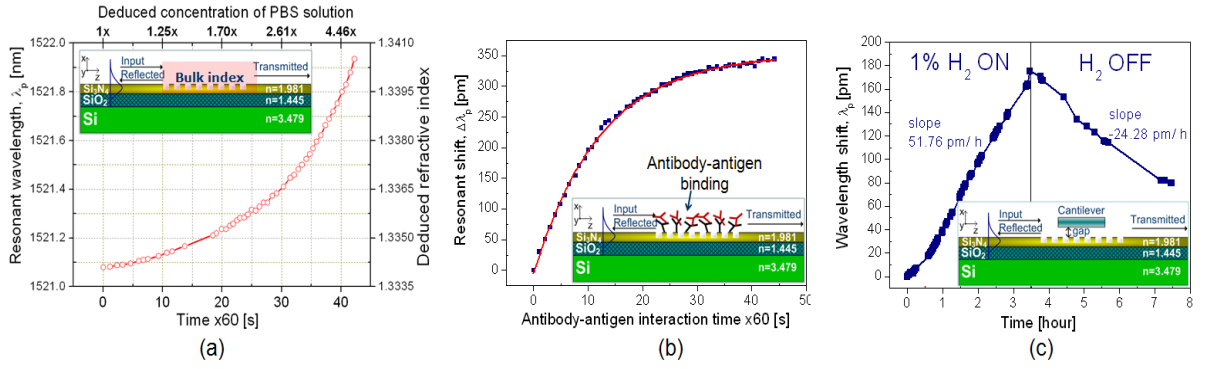

Fig. 1 Performance of devices for **(a)** measurement of salt concentration, **(b)** label-free protein sensing, and **(c)** gas sensing. Cross-sections of the sensor structures are shown in the respective insets.

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