Extended Abstracts of the 2018 International Conference on Solid State Devices and Materials, Tokyo, 2018, pp511-512

Ring Resonator Designed for Biosensing Applications Manufactured on 300 mm SOI in an Industrial Environment

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Abstract

This paper reports on the experimental characterizations of a photonic ring resonator designed for biosensing with 300 nm/RIU bulk sensitivity and a 0.125 nm resonant peak shift per nm thickness change in biological add layer. The devices were realized on a 300 nm photonic R&D platform in an industrial environment leading to marketable products.

1. Introduction

In the last decade, many designs for integrated photonics biosensors have been published. New fascinating and elaborate structures often require fabrication steps that are not compatible with industrial platforms. The SiN ring resonator sensor discussed in this paper was manufactured on the STMicroelectronics DAPHNE 300 mm Photonic R&D platform [1] and has performance levels comparable to the state-of-the-art.

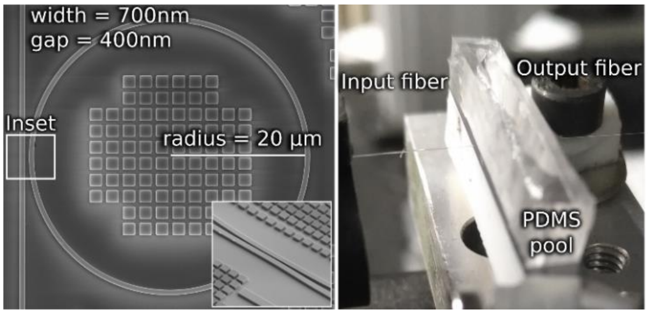

Figure 1 (a) SEM picture of the ring resonator. The inset shows the coupling area of the access waveguide and the ring. (b) Measurement setup.

2. Materials and methods

Device structure and set-up

The device layout, based on a silicon nitride (SiN) ring resonator fabricated on a SOI wafer, is shown in Figure 1(a). Subject to the DAPHNE platform design rules, simulations with the commercial software Lumerical determined the optimal geometry for the device (600 nm thick SiN waveguides). For characterization, a Polydimethylsiloxane (PDMS) fluidic reservoir was bonded on top of the device, as shown in Figure 1(b). TE polarized light from a variable wavelength fiber pigtailed laser centered at 1.55 um was injected into the bus waveguide by butt coupling. The output light from the bus waveguide was characterized with a spectrometer.

Bulk index measurements

At first, liquids of different optical indices (e.g. water, ethanol, PBS) were introduced into the PDMS reservoir to induce a shift in the resonance wavelength. The bulk index measurements provide the system's response to a homogeneous refractive index change in the volume above the structure.

Adlayer thickness change measurements

Device response to a change in adlayer thickness as a function of change in index of refraction at the surface of the sensor is the sough-after biosensor signal. As a first step, the response to the addition of the surface functionalization layer (bovine serum albumen, BSA) was determined by measuring the transmission spectrum through the bus waveguide at each of the following steps, at room temperature:

1. No liquid present;
2. Injection of the phosphate-buffered saline solution (PBS 1X buffer);
3. Injection of BSA mixed with the buffer (incubation time = 30 min, concentration = 1mg/ml);
4. Rinse with buffer;
5. Rinse with DI water and drying;

Following these measurements, the next step was to measure the response to the bonding between a target molecule (streptavidin) and the functionalization layer. Due to its stability, the biotin-streptavidin interaction is commonly used to investigate the properties of biosensors [3]. Measurements were made similarly to the procedure above, but with BSA-biotin complexes in the buffer at the third step (concentration = 1mg/ml, incubation time = 30 min). After the buffer rinse at the fourth step, streptavidin in PBS 1X buffer was injected into the fluid chamber for 30 min, followed by a final buffer rinse. A number of experiments at different streptavidin in

PBS 1X concentrations were conducted, from 1 to 10 µg/mL, to determine the calibration curve and sensitivity.

3. Results

Bulk index measurements

The bulk sensitivity of the device was calculated from measurements of the transmission spectra for 4 fluids with distinct refractive indices. Figure 2(a) plots the dependence of the resonance wavelength on the refractive index of the fluid. The slope of the fitted line defines bulk sensitivity of the device in nm per refractive index unit (nm/RIU). In the present case, the device has a 300 nm/RIU bulk sensitivity which is comparable to state-of-the-art ring resonator sensors [2]. Figure 2(b) shows transmission spectra measurements for H_2O and ethanol with the corresponding numerical simulations.

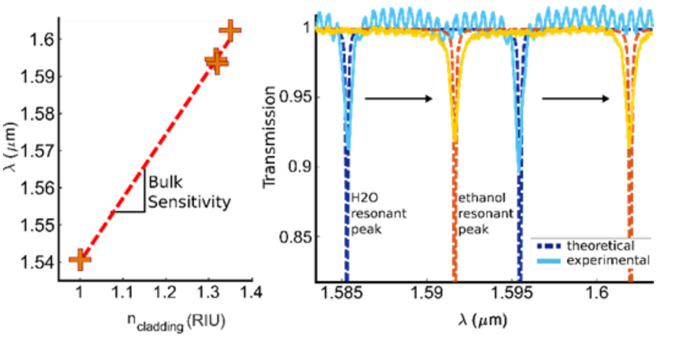

Figure 2 (a) Resonance wavelength against the refractive index of the liquids (b) Example of transmission spectra of the device for ethanol and water.

Adlayer thickness change measurements

Experiments with BSA functionalization layer with a thickness of 4 nm and a refractive index of 1.45 showed a shift of the resonant peak of 0.5 nm. It is a reasonable value compared to the spectral resolution of commercial spectrometers. This result means that the device is sensitive to small molecules (e.g. DNA). Figure 3 shows the transmission curves for pure PBS cladding and PBS cladding with the BSA add layer.

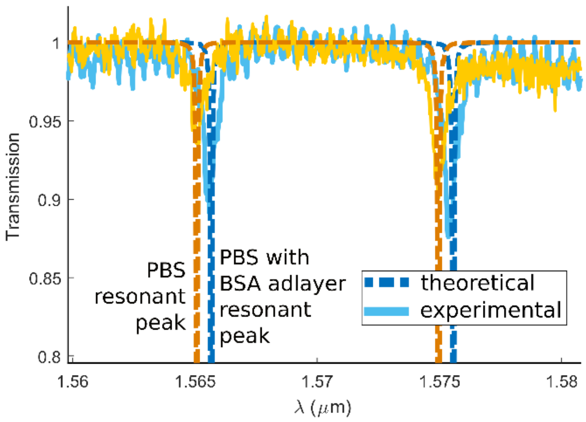

Figure 3 Transmission curves before and after the creation of the functionalization layer.

Complementary experiments to characterize the response to an analyte bonding are ongoing (for instance Biotin-Streptavidin interactions).

4. Conclusions

This paper shows that integrated photonics sensors can be manufactured with the same industrial process as other microelectronics devices: a single deep UV lithography and a well-known deposition and etching processes. In particular, a bio-sensing ring resonator with state-of-the-art bulk sensitivity (300 nm/RIU) and add layer sensitivity (0.125nm/nm) can be realized with this platform.

Acknowledgements

We would like to express sincere thanks to Ulrike Froehlich, Marine Boulade and Jean-Pierre Cloarec for their support during the biological experiments.

References

[1] C. Baudot et al., *Developments in 300mm silicon photonics using traditional CMOS fabrication methods and materials* in 2017 IEEE International Electron Devices Meeting (IEDM), 2017, pp. 1–4.

[2] T. Taniguchi et al., *Detection of antibody-antigen reaction by silicon nitride slot-ring biosensors using protein G,* Optics Communications, vol. 365, pp. 16–23, Apr. 2016

[3] Qing Liu et al., *Highly sensitive Mach–Zehnder interferometer biosensor based on*, Sensors and Actuators B, vol. 188, pp. 681– 688, Jul. 2013