Silicon photonics based evanescent sensor for absorption spectroscopy of glucose

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Diabetes is a health condition that affects a rapidly growing number of people who can all benefit from tight blood glucose monitoring. To this end we develop an implantable continuous blood glucose sensor for long-term use. The detection principle is near-infrared absorption spectroscopy, which avoids the use of reagents to ensure long-term sensor reliability and additionally, allows the detection of multiple bio-molecules apart from glucose. The core of our sensor is a miniature near-infrared spectrometer made in the high-index silicon-on-insulator (SOI) platform. The spectrometer's sensing element is a waveguide spiral whose evanescent field is attenuated according to the absorption spectrum of its environment. We target the spectral features in the first overtone (1550-1850 nm) and combination band (2000-2500 nm).
To enhance the glucose absorption signal between 2 measurements of a solution with and without glucose, the spiral length should be optimized. One can show that when the length-dependent losses, the waveguide loss α_{wg} and solution absorption loss α_{abs}, amount to 1/e, the power difference between the 2 measurements is maximized. To assess our sensing element, we designed a spiral waveguide with length of 6290.0 µm that can be accessed with optical fibers through grating couplers. The waveguide is a 220 nm thick and 450nm wide Si layer on a 2 µm thick buried oxide layer. On top of the fabricated silicon chip we processed a 100 µm thick SU8 layer with openings above the spiral and grating couplers. The fabricated result is depicted in Fig.1a.

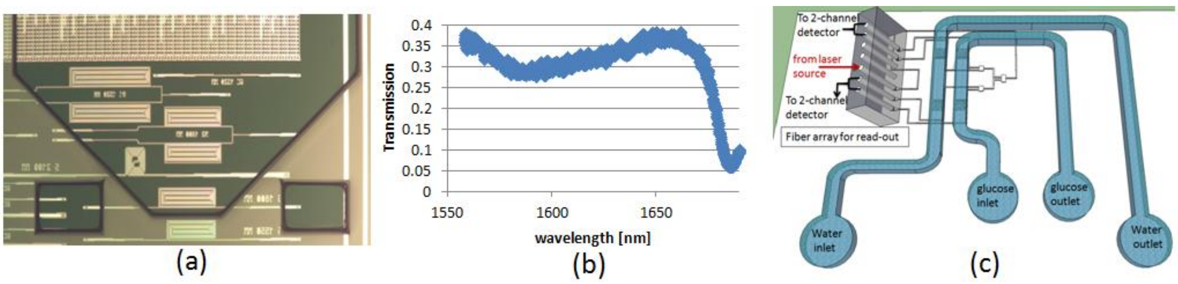

Figure 1. (a) Fabricated SOI spiral with SU8 box (b) Transmission spectrum of IPA (c) Sensor with microfluidics

The fibers are glued to the chip to minimize the noise due to mechanical vibrations. A superluminescent diode (SLED) and an optical spectrum analyzer (OSA) are used for the chip read-out. We characterize the short-term stability of the system by calculating the root mean square (RMS) noise for 100% lines [1]. The noise contribution of the source is calculated to be 248 µAU and the total set-up exhibits a noise figure of 551 µAU. The chip was evaluated by applying a drop of isopropyl alcohol (IPA) to the SU8 box. IPA was chosen because of its similar molecular bonds, hence spectrum, to glucose. The measurement result is plotted in Fig. 1b, which agrees well with the results in [2]. As the absorption features of glucose are very weak for physiological concentrations and water is a strong interferent, the noise of the present system is too high. Therefore we propose a dual-beam system in which a reference spiral is employed to eliminate the influence of both the source noise and other common interferents. We are currently fabricating a sensor as displayed in Fig. 1c. We use microfluidics in Polydimethylsiloxane (PDMS) to bring the sample solution to the chip. Two identical reference spirals and two identical signal spirals of length L_{opt} are in contact with water and a glucose solution respectively. The read-out of this sensor will be done with a fiber array. Experimental results on this sensor will be reported at the conference.

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