Integrated optical sensor using silicon ring resonators

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We report an experimental demonstration of an integrated optical sensor based on ring resonators. The device is fabricated in a Silicon-On-Insulator (SOI) platform and operates at a wavelength of 1550 nm. The transmission spectrum of the device is measured for different substances on the top of the sample varying their refractive index. After measurements, a linear shift of the resonances of the ring resonator is observed, obtaining a sensitivity of 46 nm/RIU (Refractive Index Units) and a detection limit of $2.1\cdot10^{-3}$RIU, which is in the order of other reported results for Silicon ring resonators [1], but this sensitivity is improved using slotted waveguides [2].

Label-free biosensors are becoming more stables and reliable with a high relying level [3]. So that, a biosensor based on integrated microring resonators in SOI is reported in this work. One of the main advantages of these devices is their size, giving structures with footprints in the order or tenths of μm^2. Moreover, high sensitivities can be achieved. Fabrication process for devices in SOI technology is fully CMOS compatible, making it very profitable for mass production and achieving very cost-effective devices.

SOI wafers used in this work have a top 250nm-thick silicon layer of and an underlying 3µm-thick silicon oxide substrate. The structures were exposed using high resolution e-beam lithography and transferred to the silicon using an ICP (Inductive Coupled Plasma) etching. The fabricated ring resonator is shown in Fig. 1. The bent sections of the ring have a radius of 3 µm, the racetrack is 20 µm long and coupling regions of 1 µm have been created in the ring resonator. The coupling gap is around 75 nm. The waveguides' width is 500. A theoretical FSR (Free Spectral Range) of 13 nm is obtained for these parameters.

We coupled TE-polarized light from an ASE (Amplified Spontaneous Emission) source to the device using a lensed fiber, and a second lensed fiber was used at the output of the device to collect the light and display the spectrum in an optical spectrum analyzer. Different substances were dropped over the chip and the shift of the resonances was measured. We used different alcohols with different refraction indices: ethanol (n=1.361), isopropyl alcohol (n=1.376) and acetone (n=1.359). Spectra ranging from 1540 nm to 1560 nm were measured in order to see two resonances. The resolution was set to 20 pm.

Figure 3 shows the position of the resonance when depositing ethanol and isopropyl alcohol. Different measurements for each alcohol are depicted, showing a good repetitivity of the results. The detection limit achieved is $2.1\cdot10^{-3}$ RIU. Using the shift in the position of the resonances we can obtain the sensitivity curve plotted in Fig. 4, giving a value of sensitivity of 46 nm/RIU.

To conclude, in this work we have presented the experimental results of an integrated biochemical sensor based on a ring resonator on SOI technology, obtaining values of sensitivity of 46nm/RIU, what is in the same order of magnitude as for other recent works. Some improvements still to be included such as Peltier elements for temperature controlling or combining a Mach-Zehnder structure with the rings in order to have an interferometric scheme. The main advantage of this device is the possibility of obtaining highly integrated and low cost sensors, with a high potential for several applications when combined with surface functionalization techniques.

References:

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Figures:

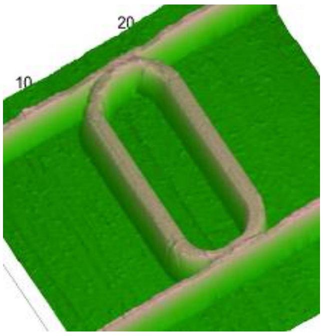

Figure 1) AFM picture of the fabricated ring resonator. The bent sections have a radius of 3 µm, the racetracks have a length of 20 µm, and a coupling region of 1 µm has been used.

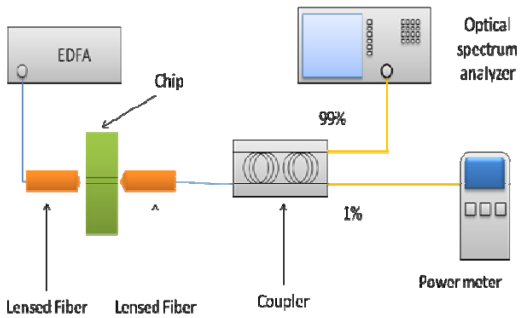

Figure 2) Scheme of the optical set-up used to carry out the measurements.

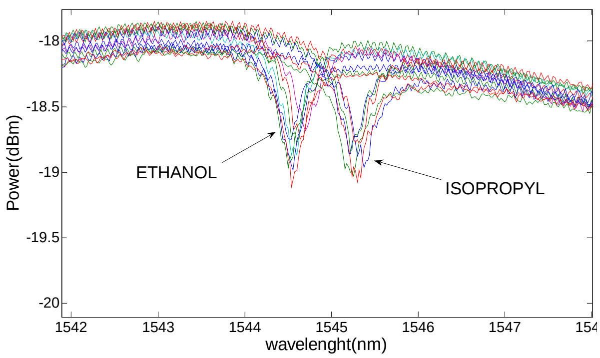

Figure 3) Transmission spectra of the ring resonator for two different alcohols. Several measurements are plotted for each substance, in order to depict the repetitibility of the measurements.

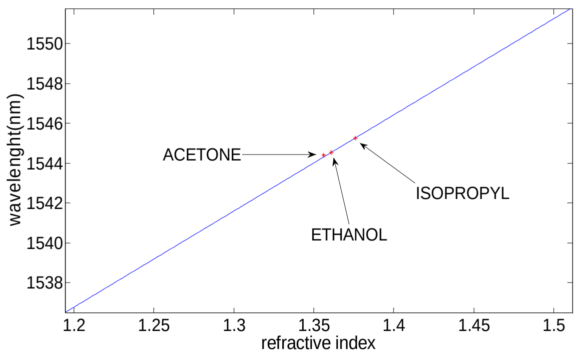

Figure 4) Resonance wavelength (nm) shift versus refractive index of the deposited substance.