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1D PHOTONIC CRYSTAL SENSOR INTEGRATED IN A MICROFLUIDIC SYSTEM

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A refractive index sensor was designed as a 1D resonator incorporated in a microfluidic channel, where aqueous solutions were injected. A sensitivity of 480 nm/RIU and a minimum difference of Δn=0.002 were determined.

OCIS codes: (130.6010) Sensors; (130.3120) Integrated optics devices

A novel optofluidic system consisting of a one dimensional photonic crystal, integrated planar waveguides and electrically insulated fluidic channels is presented. The one dimensional photonic crystal consists of an array of silicon oxynitride pillars, which is used as a resonator for on-column label free refractive index detection. The resonator is part of a microfluidic channel designed for electrochromatography. This approach differs significantly from previous work, since the photonic crystal is not an array of holes in a Si membrane [1], but an array of pillars (Fig. 1). This fact enables the injection of fluid along the device plane, thus readily integrating the 1D photonic crystal within planar microfluidic channels [2].

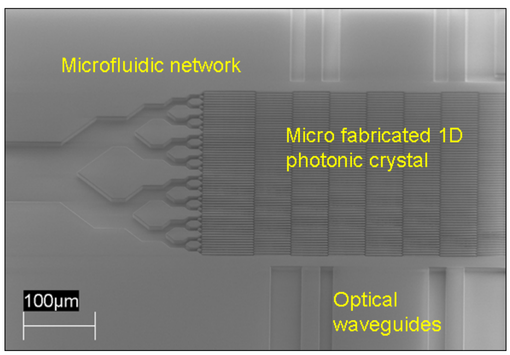

Figure 1 – SEM picture of the 1D photonic crystal, integrated waveguides and microfluidic channel, before anodic bonding of a glass lid. The microfluidic branching structure to the left ensures a constant flow resistance in the whole channel network.

Furthermore, it is fabricated in glass and not in silicon to support electroosmotic pumping of the liquid, thus significantly simplifying the external instrumentation, since pumps are avoided. This also makes it possible to use it as a detector in electrokinetic separation systems, thereby greatly extending the possible applications of photonic crystal sensors.

Infrared light (λ = 1.5 – 1.6 μm) was butt coupled in and out of the waveguides. The resonator with a thin layer of 200 nm a-Si on the pillars sidewall had a pitch of 5 μm. Mili-Q water and three different aqueous solutions of ethanol (10 %, 25% and 50% (v/v)) with refractive indices ranging from n = 1.3330 to 1.3616 were pumped into the column/resonator (9 pillar array) and the transmission spectra were recorded. Increasing the fluid refractive index leaded to redshifts in the resonant wavelengths as can be seen in Fig. 2. Our device yielded a maximum sensitivity of $\Delta\lambda/\Delta n$ = 480 nm/RIU and a Q-factor of 150.

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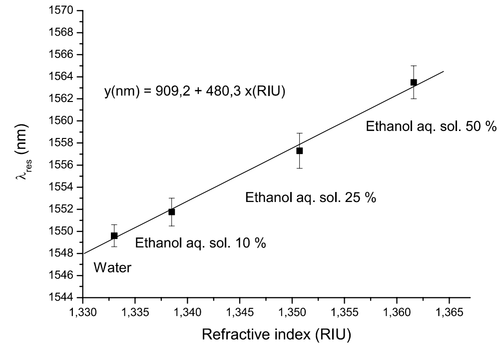

Figure 2 - Resonant wavelength plotted as a function of refractive index (n) for a 1D photonic crystal consisting of 9 pillars. Linear fit of the experimental data yields a sensitivity $\Delta\lambda/\Delta n \approx 480$ nm/RIU. The error bars refer to fluctuations on the resonant wavelength after successive injections of Mili-Q water and aqueous solutions of ethanol - 10 %, 25 % and 50 % (v/v).

Chip improvements were done by increasing the number of pillars, to 32 pillars, in the fluidic channel and by pumping the fluid of interest, 4 mM Acetominophen in 5 mM Tetra Borate buffer, electrokinetically (Fig 3). This was achieved, by applying a 1 kV potential drop between fluidic reservoirs at the ends of the channel. This approach reduces considerably the mechanical noise and enabled a 1.4 nm shift to be recorded, whereas in the previous design only 2.2 nm shift could be measured. This enabled a minimum refractive index difference of 0.002 to be measured.

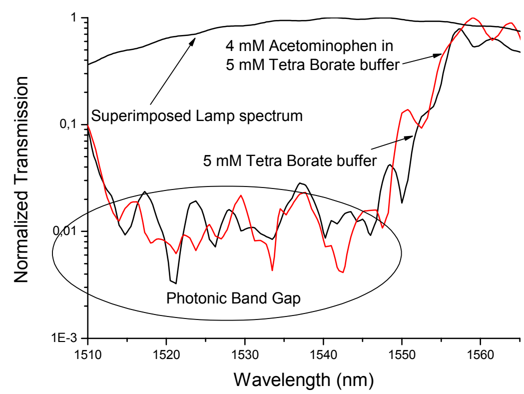

Figure 3 – Normalized transmission spectra of a 1D photonic crystal consisting of 32 pillars in the microfluidic channel. 4 mM Acetominophen in 5 mM Tetra Borate buffer were injected electokinetically, enabling a minimum shift of 1.4 nm to be measured.

So far this is the highest sensitivity achieved in similar devices, with the added benefit of using the photonic structure for optical detection and in the future for chromatography purposes. Improvement of the Q-factor will be achieved by designing a resonator with a smaller pitch using E-beam lithography instead of conventional UV lithography.

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