Fabrication considerations for differential absorption based optofluidic sensors to measure ionic content in water

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Introduction: The main conventional method to analyse ionic content in water is ion chromatography. Though this method works very well the time required for a sample to be collected and analysed is long (>1day). Also this method requires experts and an analytical lab. [1]

Optical techniques could be the solution to these problems: the integration of these techniques in optofluidic devices enables analysis on-site and on-line, furthermore, the use of these sensors enables remote signal data processing and localisation of a contamination. Ideally the implementation is label free and has a long life time. [2]

Not all optical methods are suitable for identification and quantification of ionic content. Fluorescence and chromatography methods require labels. Raman and IR absorption methods are hard to integrate and methods based on the real part of the refractive index give excellent detection limits, but fail to identify compounds without a filter (e.g. a membrane or coating).

An alternative optical method, yet to be utilized, is based on the difference in absorption of demineralized water and a saline solution. Ionic content in water can be identified and quantified using the spectral region of 940 – 1040 nm as shown in previous work [3]. That study was performed with a commercial photometer, but this optical technique could be integrated. [4] The spectral window allows for widely available cheap sources and detectors.

Design of device: The main drawback of the proposed method is the comparatively small differential absorption. For this reason we optimized the sensing length on a chip considering different on-chip losses and utilized interferometric measurement techniques. The expected normalized intensity of the signal for waveguide without losses can be calculated using the following equation, which follows from the Lambert-Beer law:

$$L_m = \frac{625}{C} log_{10}\left(\frac{C}{25} + 1\right) \quad (1)$$

This equation shows the normalized signal intensity to be hardly influence by the concentration. Therefore we show in Figure 1 the normalized signal intensity by the sensing length for different waveguide losses with a fixed (0.5 M) concentration of an electrolyte.

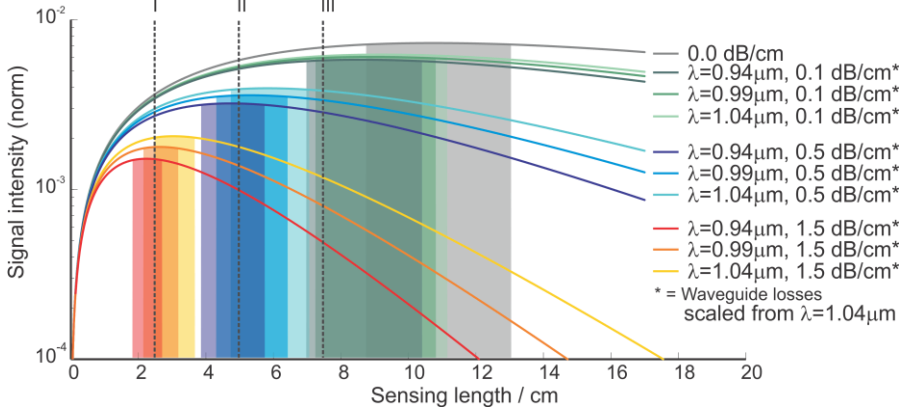

Fig. 1 The expected normalized intensity due to a 0.5 M concentration electrolyte is plotted against the sensing length. The grey line presents a waveguide without losses, while the green, blue and orange lines present waveguides with losses of 0.1, 0.5 and 1.5 dB/cm at λ=1 μm, respectively. The wavelength dependent losses are calculated with the scaling factor $(\lambda_0 / \lambda_1)^4$. Dotted lines I, II and III are plotted at 2.5 cm, 5.0 cm and 7.5 cm, respectively. The shaded areas represent 95% of the signal intensity for a given set of parameters.

We present optimal sensing lengths for differential absorption measurements on a chip. We also present calculations (using Phoenix simulation software) to determine the optimized cross section of the sensing and guiding waveguides, balancing single mode operation over 100 nm bandwidth, maximized sensitivity, minimized losses and maximized tolerances for fabrication. The designed optofluidic chips have been fabricated and the propagation through one of these devices is shown in figure 2.

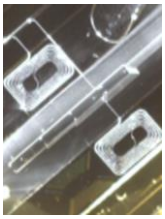

Fig. 2 Microscopic topview image of propagation through a fabricated optofluidic device.

References

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