Photo-actuated Ionogel Microvalves for Real-time Water Quality Analysis in a Micro-fluidic Device

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Introduction

In the recent years, advances in micro-fluidic techniques for environmental applications have brought wide opportunities for improving water quality monitoring. However, the development of fully integrated micro-fluidic devices capable of performing complex functions requires the integration of micro-valves with an appropriate performance, since they are essential tools for the control and manipulation of flows in micro-channels.[1]

Here we present an attractive approach for water quality analysis, nitrite determination, based on photo-switchable ionogel actuators wherein the micro-valve opening/closing mechanism is controlled by simply applying localised white light irradiation using light emitting diodes (LEDs). The nitrite concentration of standard solutions is detected by a highly sensitive, low cost wireless paired emitter detector diode device (PEDD).

Microfluidic chip with photoswitchable ionogel microvalves

- The incorporation of ionic liquids within responsive gel matrices (ionogels) produces hybrid materials with many advantages over conventional materials such as tunable hydrophobic and hydrophilic nature, chemical and thermal stability.
- Depending on the ionic liquid, ionogels give the possibility of tuning several micro-valve actuation times and so independently control liquid flows within the channels under a common illumination source.[2]
- Non invasive, non-contact stimuli such as light, offers improvements in versatility during manifold fabrication, and precise control of the actuation mechanism.

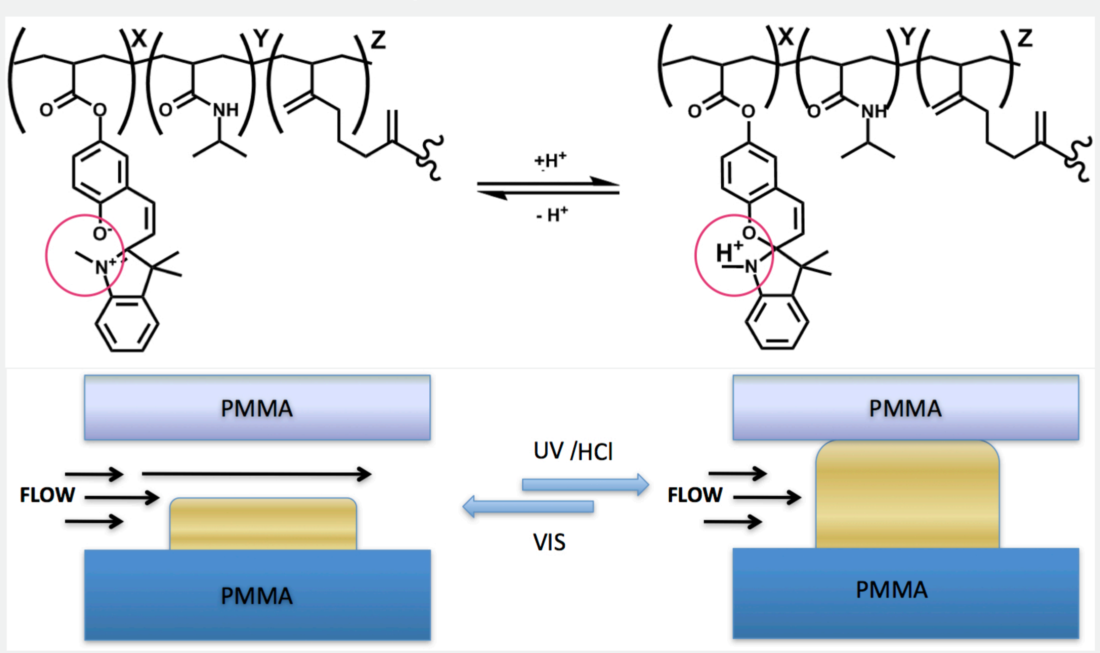

Fig. 1. Scheme of the photoswithchable polymer matrix and schematic of the valve actuation.

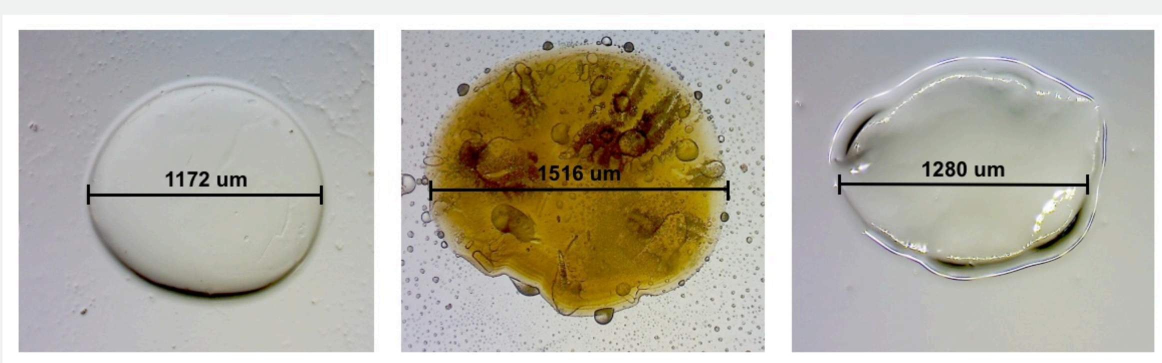

Fig. 2. Ionogel microstructure after photopolymerisation (left), immersion in HCl for 2 hrs (middle) and white light irridiation (right).

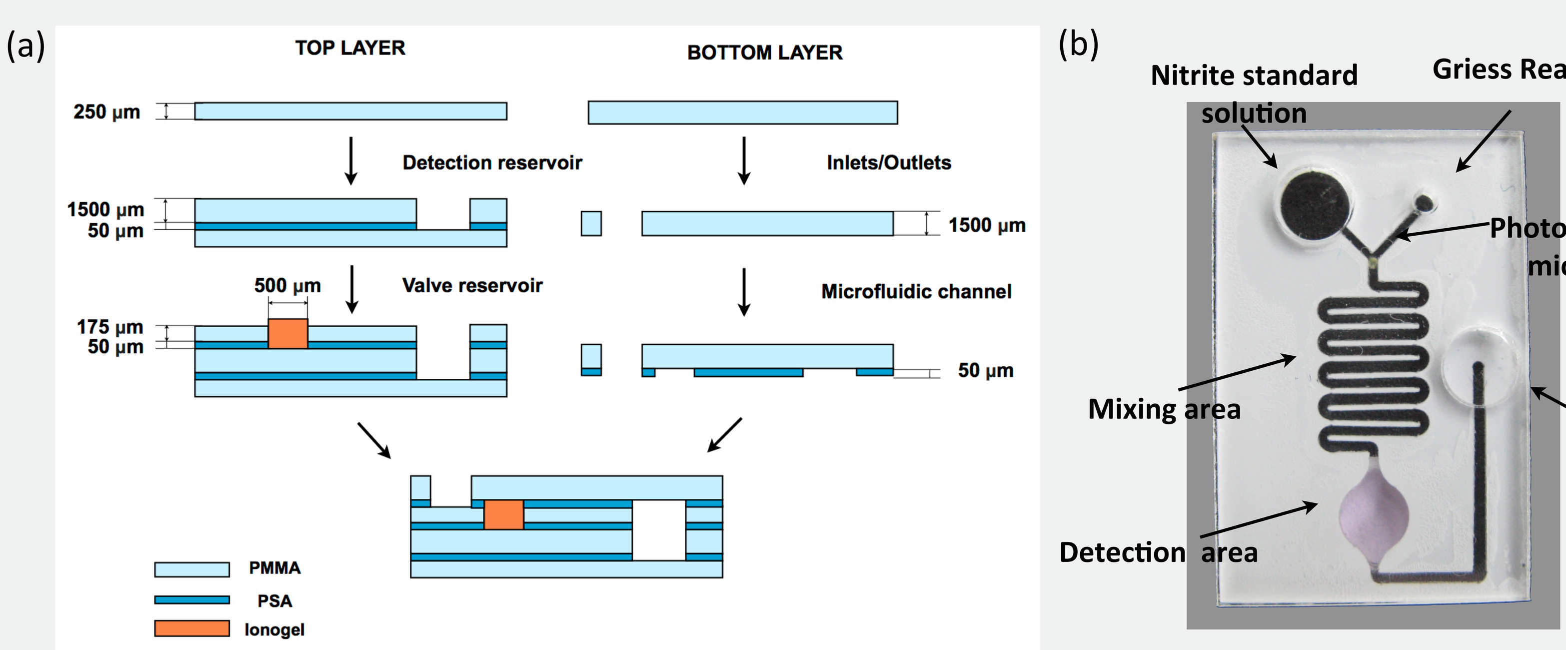

Fig. 3. a) Schematic representation of the micro-fluidic device fabrication procedure. b) Picture of the micro-fluidic device fabricated in PMMA : PSA polymer by CO_2 laser ablation.

Nitrite detection with PEDD device

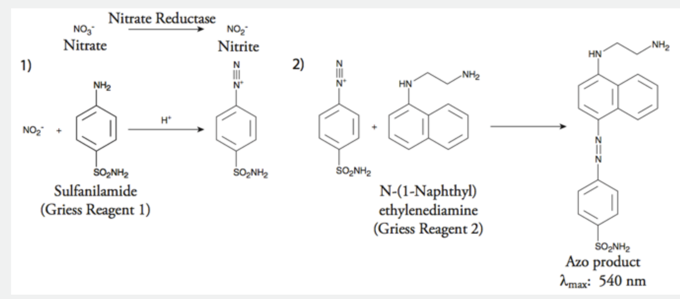

Fig. 4. Mechanism of nitrite detection employing the Griess reaction method [3].

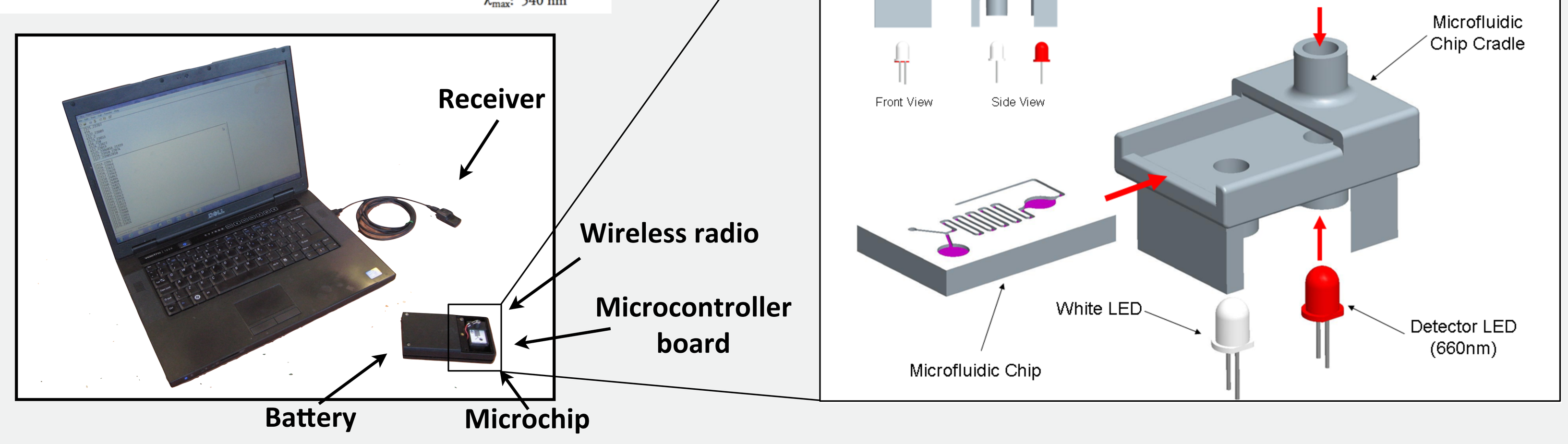

Fig. 5. Prototype configuration of the PEDD device with schematic of the in house designed cradle system.

Results

A series of microvalves were photopolymerised *in-situ* within micro-fluidic channel. Their response due to hydrochloric acid (HCl) (swelling; closing the channel) and white light irridiation (shrinking; opening the channel) were tested (Fig. 6).

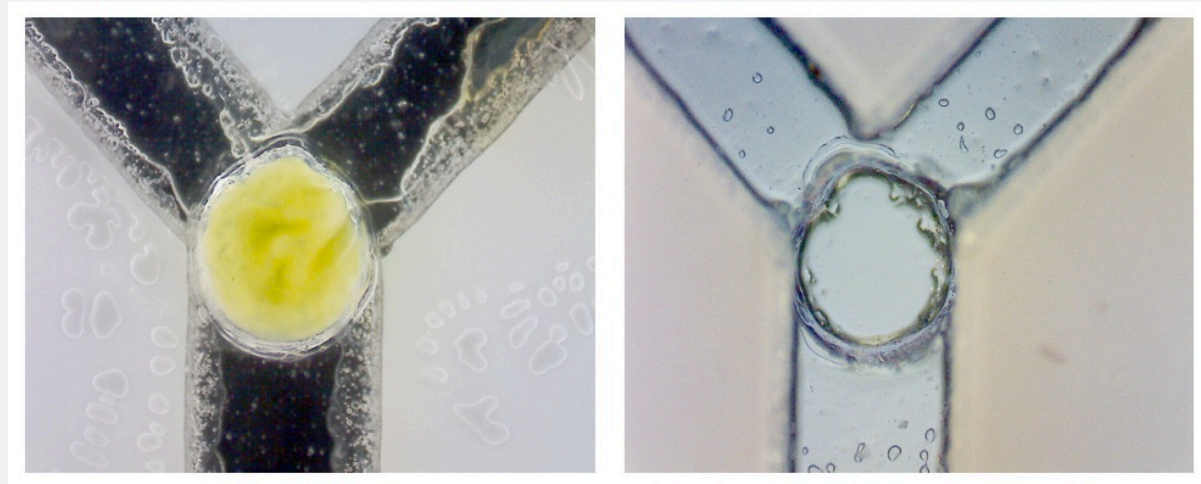

Fig. 6. Ionogel micro-valve in closed (left) and opened (right) state.

The development of the nitrite Griess reagent complex colour intensity was monitored for the detection of NO_2 using the UV/VIS spectrophotometer (off-chip) and PEDD device (on-chip), by taking an absorbance measurement at a λ_{max} of 540 nm for 30 minutes.

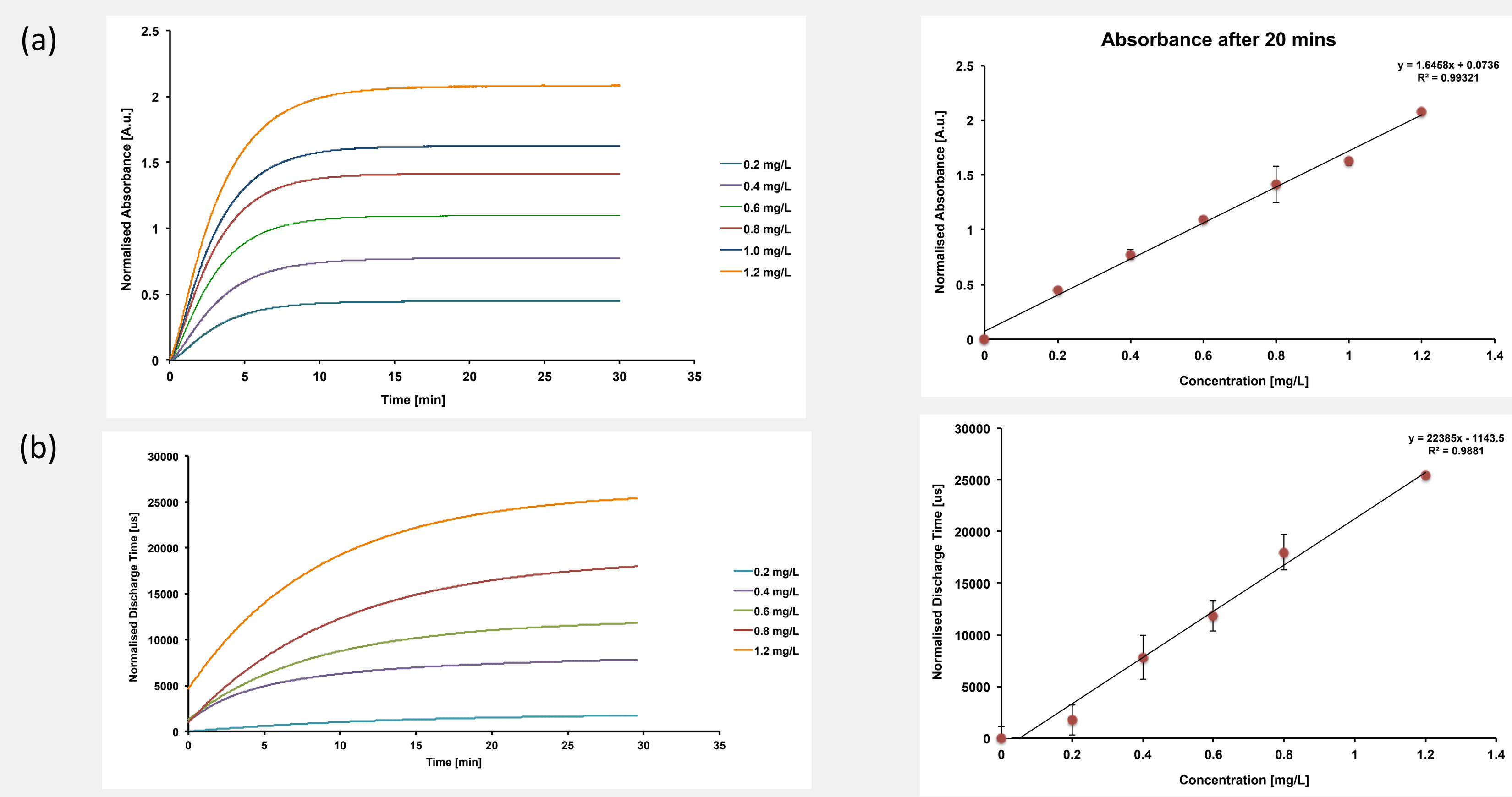

Fig. 7. Kinetic study of the colour formation monitored at a wavelength λ_{max} 540 nm between NO_2 and Griess reagent (n = 3) (left side) and absorbance *versus* nitrite Griess reagent complex concentration (right side) using a UV-Vis spectrometer (a) and the PEDD system (b).

Conclusions

A novel and attractive approach for the *in situ* detection of nitrite, employing the Griess reaction, method was presented. Photo-control of the micro-valve actuation facilitates non-contact and non invasive operation. It is clear that such photo-responsive ionogel micro-valves have the potential to greatly enhance the fabrication and subsequent operation of multifunctional micro-fluidic devices. Moreover, the microfluidic chip combined with a low-cost optical sensor, PEDD, allows for monitoring the nitrite of water samples in real time. Apart from the low-power detection and the communication system, the integration of a wireless communication device allows the acquisition of parameters to be controlled remotely and to be adjusted according to individual needs.

References

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