

PORTABLE LAB-ON-A-DISC SYSTEM INTEGRATING PHOTO-SWITCHABLE MICRO-VALVES FOR *IN-SITU* AQUATIC ENVIRONMENTAL MONITORING

Monika Czugala¹, Damian Maher¹, Robert Burger², Kevin J. Fraser¹, Jens Ducree², Dermot Diamond¹ and Fernando Benito-Lopez¹

¹ CLARITY: Centre for Sensor Web Technology, ² Biomedical Diagnostics Institute, School of Physical Sciences, National Centre for Sensor Research, Dublin City University, Dublin, Ireland

ABSTRACT

This work describes the first use of a portable centrifugal microfluidic analysis system (CMAS) for on-site lab-on-a-disc water quality monitoring. The centrifugal microfluidic platform designed for the detection of nitrite in multiple water samples incorporates photo-switchable microvalves, which are easily controlled using white light irradiation. Calibration of the CMAS system resulted in a linear response that obeys the Beer-Lambert Law. Excellent correlation of results between the CMAS device and a standard UV-Vis spectrophotometer were obtained.

KEYWORDS: Centrifugal Microfluidics, Colorimetric Analysis, Paired Emitter Detector Diode (PEDD), CMAS, nitrite

INTRODUCTION

Nowadays, there is great interest in *in-situ* monitoring allowing fast data acquisition for environmental analysis. The challenge is to develop portable devices that could be used in remote locations, which would ultimately enable dynamic monitoring. Typical analysis methods are very costly and time consuming, therefore addressing the need for a simple and cost-effective sensor is crucial. Micro total analysis systems provide a route to the generation of analytical instruments that can be operated in remote locations, enabling *in-situ* analysis. However, the development of fully integrated micro-fluidic devices requires the integration of micro-valves with an appropriate performance, as they are essential for the manipulation of flow in micro-channels. The incorporation of ionic liquids with a photochromic compound (benzospiropyran) within responsive gel matrices provides a hybrid material (ionogel) with many advantages over conventional materials [1]. The undeniable advantage of ionogel microvalves arise from the use of non invasive stimuli such as light, offering improvements in versatility during manifold fabrication and precise control of the actuation mechanism. The microvalve opening/closing mechanism can be controlled by applying localised white light irradiation using a low cost light emitting diode for example.

In this report, we present the design and development of a portable centrifugal microfluidic analysis system (CMAS) for on-site lab-on-a-disc water quality monitoring. Unlike the first generation system presented in MicroTAS 2011 [2], the new CMAS device employs not only colorimetric chemical detection, but also centrifugal disc spinning, enabling manipulation of fluids and analysis on site. We also present the first use of photo-switchable ionogel micro-valves in a lab-on-a-disc platform, which enables *in situ* nitrite detection of water samples.

EXPERIMENTAL

The centrifugal microfluidic platforms were fabricated in laminated acrylic and adhesive layers (Fig. 1). They contain several micro-fluidic systems with two inlet chambers - one for water sample loading and the other for Griess reagent. In the micro-channel, which connects the chambers with the detection area, the micro-valves were *in situ* photo-polymerised (Fig. 2). On the both sides of the valve additional inlets were fabricated to feed the valve with the acidic solution, allowing it to swell (close the channel) (Fig. 1c).

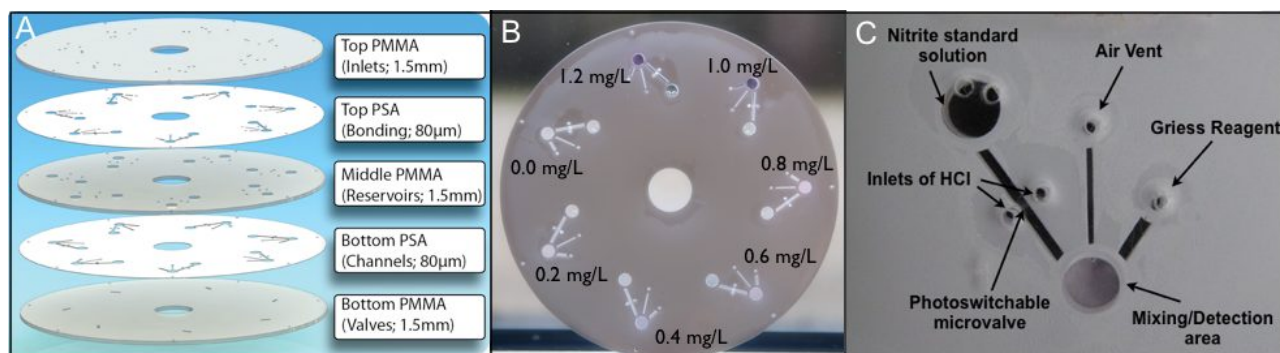


Figure 1: a) Scheme showing the assembly of the micro-fluidic CD, b) picture of the Lab-on-a-Disc and channel consisting of seven microfluidic systems and c) magnification of a single microfluidic system consisting of three chambers.

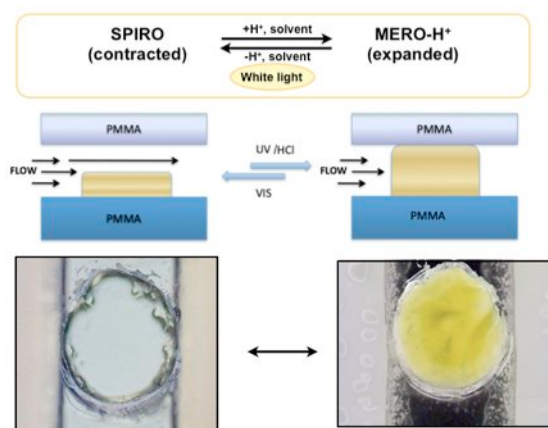


Figure 2: a) Scheme of the photo-switchable polymer matrix and schematic of the valve actuation b) Ionogel micro-valve in opened (left) and closed (right) state.

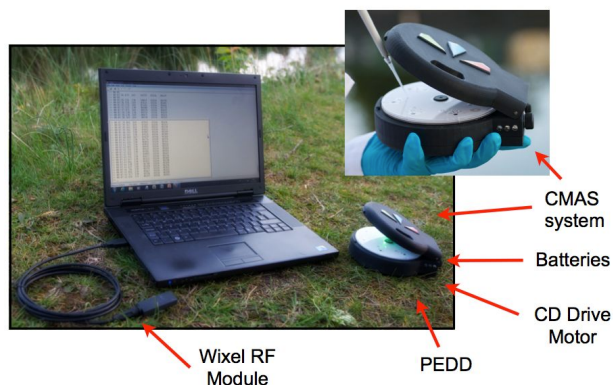


Figure 3: Portable centrifugal microfluidic analysis system.

A portable, in-house designed and fabricated CMAS that enables *in-situ* rotation of the disc and accurate measurements is presented in Fig. 3. A pulse-width modulation (PWM) controlled motor enables spinning of the disc in the wide range of speeds (500 – 4000 rpm), thus allowing for the loading of the samples to the detection chambers. The system is controlled wirelessly *via* a laptop serial interface, allowing the user to start/stop the CD, control the speed, alignment / detector LEDs and read the output of the detector. The detection system uses a low cost paired emitter detector diode (PEDD) achieving excellent signal-to-noise ratio and sensitivity. The optical emitter-detector pair is easily interchangeable allowing a wide range of centrifugal micro-fluidic layouts to be implemented using this system.

Nitrite detection was carried out employing the Griess reaction method, leading to the formation of an azo dye that can be detected at 547 nm (Fig. 4) [3]. After loading the Griess reagent and water sample in the upper chambers, rotation at 1000 rpm forced the liquids towards the detection chambers. For kinetic studies the micro-valves were in the closed state, avoiding fluids flowing through the channel. Next, the white LED was switched on for the reaction chamber of interest, resulting in the valve shrinking, thus opening of the desired micro-channel. Subsequent spinning of the CD allowed for loading of the fluid to the detection chamber, where mixing and the readout took place.

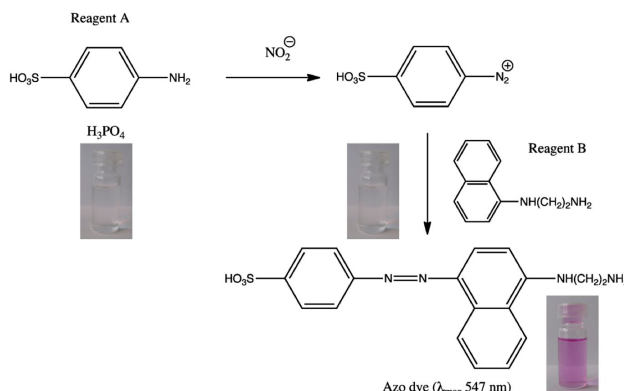


Figure 4: Mechanism of the nitrite detection employing the Griess reaction method [3].

RESULTS AND DISCUSSION

To demonstrate the utility of the system, a study of the colour formation between NO_2^- and Griess reagent was performed using both the CMAS and UV-Vis spectrophotometer for control (Fig. 5). The development of the nitrite Griess reagent complex colour intensity was monitored for the detection of NO_2^- by taking absorbance measurement at λ_{max} of 540 nm for 30 mins. A linear correlation between the discharge time and the nitrite Griess reagent complex concentration was obtained ($R^2=0.99$), which aligns well to the calibration curve obtained with UV-Vis spectrophotometer (Fig. 5, right side).

Next, freshwater samples from 5 random locations around Ireland were measured at 540 nm comparatively using the CMAS and a UV-Vis spectrophotometer for control. Fig. 6. shows excellent correlation between nitrite results obtained using the CMAS system and UV-Vis spectrophotometer.

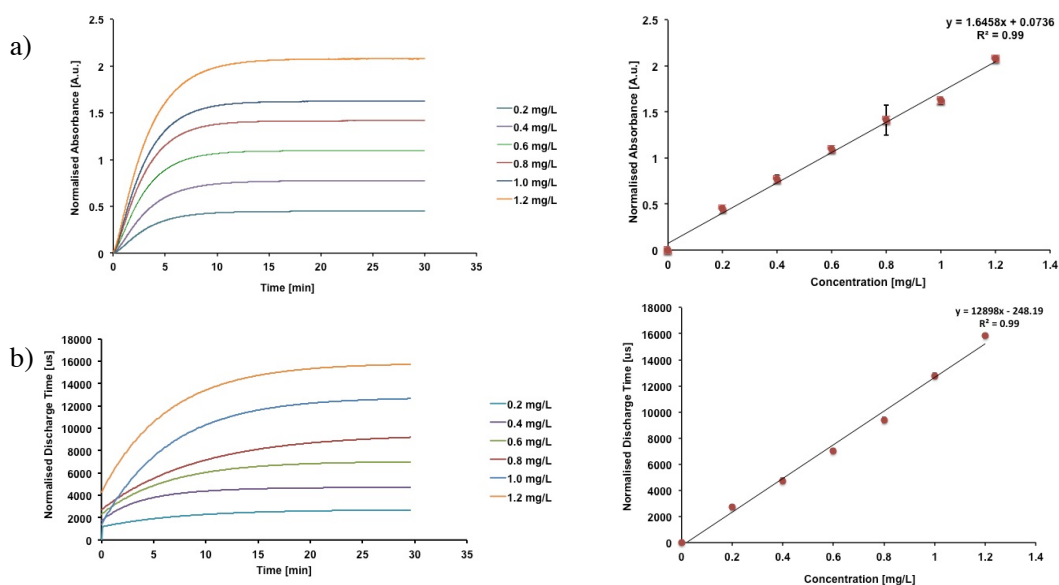


Figure 5: Kinetic study of the colour formation between NO_2^- and Griess reagent ($n = 2$) (left side) and absorbance versus nitrite Griess reagent complex concentration (right side) using a UV-Vis spectrometer (a) and the CMAS system (b).

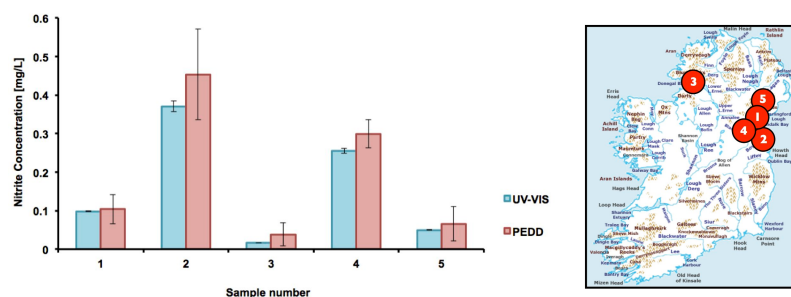


Figure 6: Water nitrite analysis using a bench-top UV-VIS spectrometer and the CMAS device and a map of the sampling places ($n = 3$).

CONCLUSION

This work successfully demonstrates the portable capabilities of the system, which in combination with the centrifugal platform provides the flexibility needed for on-site monitoring of water samples. The integration of a wireless communication allows the acquisition of parameters to be controlled remotely and to be adjusted according to individual needs, in addition to enabling data transfer. Future work will be focused on the further incorporation of additional assays within the centrifugal platform, thus enabling multiparameter analysis of water samples using single platform.

ACKNOWLEDGEMENTS

This work was supported by Marie Curie ITN funded by the EC FP7 People Program and Science Foundation of Ireland under grant 07/CE/I1147. K.J.F acknowledges the European Commission for financial support through Marie Curie Actions International Reintegration Grant (IRG) (PIRG07-GA-2010-268365) and Irish Research Council for Science, Engineering and Technology.

REFERENCES

1. F. Benito-Lopez, R. Byrne, A. M. Răduță, N. E. Vrana, G. McGuinness, D. Diamond, *Ionogel-based light-actuated valves for controlling liquid flow in micro-fluidic manifolds*, Lab Chip, vol. 10, pp.195-201, (2010).
2. M. Czugala, R. Gorkin, T. Phelan, J. Ducree, D. Diamond and F. Benito-Lopez, *Novel optical sensing system based on wireless paired emitter detector diode device and ionogels for Lab-on-a-Disc water quality analysis*, MicroTAS 2011, Seattle, USA, pp. 1418-1420, (2011).
3. J. F. MacFaddin, *Nitrate/nitrite reduction tests*, In: *Biochemical tests for identification of medical bacteria*, 3rd ed. Lippincott Williams & Wilkins, Philadelphia, pp. 348-362, (2000).

CONTACT

Monika Czugala + 353 858206607, E-mail: monika.czugala2@mail.dcu.ie