Pump Less Wearable Micro-fluidic Device for Real Time pH Sweat Monitoring

DCU NCSR National Centre for Sensor Research

CLARITY Centre for Sensor Web Technologies

Fernando Benito-López, Shirley Coyle, Robert Byrne, Alan Smeaton, Noel E. O'Connor, Dermot Diamond

CLARITY: Centre for Sensor Web Technologies

National Centre for Sensor Research, Dublin City University, Dublin, Ireland

Introduction

Nowadays, Micro-Total-Analysis-Systems and Lab-on-a-Chip technology are widely used in analytical chemistry and biotechnology [1] but it is still rarely used in other areas like sports science. In this field, wearable sensors are becoming increasingly employed, through the use of embedded transducers or smart fabrics for monitoring parameters like breathing rate and heart rate [2]. However, due to their relative complexity, there is very little activity in the development of real-time wearable chemo/bio sensing for sports applications (Fig.1).

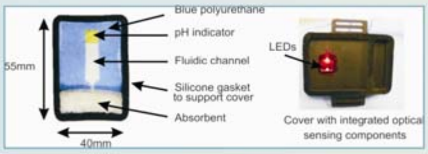

Figure 1: Fabric-based sweat analysis system, developed as part of the BIOTEX project.

In contrast to transducers, wearable chemo-/bio-sensing requires that the desired sample of analysis, usually a body fluid such as sweat, is delivered to the sensor's active surface whereon a reaction happens and a signal is generated. Moreover the system must be low cost, while still being robust, miniature, flexible, washable, reusable or disposable [3]. All these requirements point to micro-fluidic devices as the key tools for improving wearable chemo-/bio-sensing.

This poster presents the fabrication and the performance of a novel, wearable, robust, flexible and disposable micro-fluidic device which incorporates micro-Light Emitting Diodes (μ-LEDs) as a detection system, for monitoring in real time mode the pH of the sweat generated during an exercise period.

Chip Fabrication

Schematic representation of the fabrication of the microchip structure (Fig. 2). The microchip (2 x 3cm) is easily fabricated using poly(methyl-methacrylate) and pressure-sensitive adhesive in three layers using a CO_2 ablation laser. Picture of the final micro-chip (Fig.3).

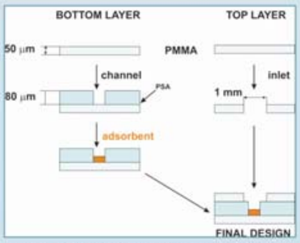

Figure 2: Schematic representation of the micro-fluidic device fabrication procedure.

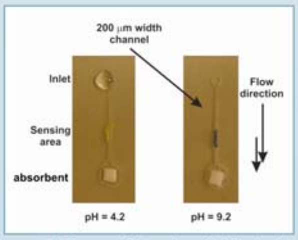

Figure 3: Picture of the micro-fluidic device.

Since human sweat generally lies in the region of pH 5-7, bromocresol purple has been chosen as it shows a colour change from yellow to blue over this pH range. The sweat is drawn into the sensing area by an absorbent fiber placed at the end of the channel.

Acknowledgments

The project has been carried out with the support of the Irish Research Council for Science, Engineering and Technology (IRCSET) fellowship number 2089, Science Foundation Ireland under grant 07/CE/I1147 and the European Union (Biotex FP6-2004-IST-NMP-2).

Detection System

* The detection takes place by means of two μ-LEDs placed above and below the sensing area.

* One of the μ-LEDs acts as light source while the other is reverse biased and acts as a detector.

* Both μ-LEDs are controlled by a microcontroller (Lilypad Arduino) which is designed for wearable applications as it has pins that can be stitched to using conductive threads.

* This link could be easily replaced by a wireless connection by attaching a Bluetooth® modem (BlueSMiRF silver) to the Arduino microcontroller.

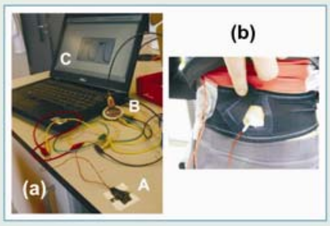

Figure 4: (a) Set-up.
A) Micro-chip and μLEDs system in a simple adhesive plaster.
B) Arduino Lilypad microcontoller
C) Data transferred from microcontroller to laptop using serial connection.
(b) Micro-fluidic device in contact with the skin protected by a velcro belt.

The experimental set-up used for pH measurements is shown in Fig.4 (a). Fig.4 (b) shows the microfluidic device in contact with the skin before exercise performance. The micro-fluidic device is protected from the external influence, like light, by a velcro belt.

Performance of the device

Fig.5 shows two different pH measurements using the same microfluidic device. The light intensity varies from 2000 counts when the pH is higher than 7 (blue) down to 250 counts when pH is below 5 (yellow).

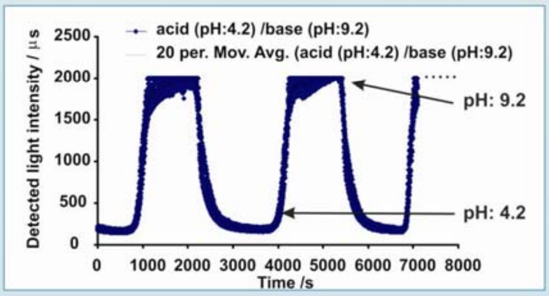

Figure 5: pH response of the sensing area of the micro-fluidic device.

These results are reproducible, suggesting that the device can be used for on-line monitoring of sweat during sport performance and training.

Conclusions

We have showed here the fabrication of a novel, wearable, robust, flexible and disposable microfluidic device. The system incorporates micro-Light Emitting Diodes (μ-LEDs) as a low-cost and low-power detection system.

The device was shown to respond over the pH range typically encountered in exercise sessions, implying that it could be employed for real-time monitoring of sweat pH.

Moreover, the device is flexible and comfortable to wear providing an unobtrusive and non-invasive method for the analysis of sweat during exercise.

1. Ohno K., Tachikawa K., Manz A. Microfluidics: Applications for analytical purposes in chemistry and biochemistry, Electrophoresis 2008; 29: 44434453.
2. Brady S., Dunne L. E., Lynch A., Smyth B., Diamond D. Wearable Sensors - What is there to sense?, 'Studies in Health Technology and Informatics', 117 (2005) 8088.
3. Diamond D., Coyle S., Scarmagnani S., Hayes J. Wireless Sensor Networks and Chemo-/Biosensing, Chem.Rev. 2008; 108:652679.