SMART DISPOSABLE PLASTIC LAB-ON-A-CHIP FOR POINT-OF-CARE TESTING (POCT)

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ABSTRACT

This paper presents the development of smart, disposable biochip for point-of-care testing (POCT) applications. The key features of the biochip include: integrated metallic microneedle for sampling, smart passive microfluidic control system, integrated on-chip air bursting detonators for fluidic driving and biosensor array for analyzing clinically relevant parameters from human blood. An on-chip calibration solution pouch is also included, allowing dispensing of a known concentration calibration buffer. The use of calibration solution cancels out interfering signals from external environment such as temperature variations. The biochip performance has been characterized and the fully-integrated biochip has been used to successfully monitor *Glucose*, *Lactate*, and *Oxygen* concentration from human blood[1].

KEYWORDS: ***Biochip, disposable, calibration solution, point-of-care testing***

INTRODUCTION

Clinical diagnostics is rapidly emerging as a vital application area for μTAS devices due to the advantages of microscale devices, such as fast reaction times and low sample/reagent volume consumption, low cost. In order to achieve to desired biochemical functionality a smart microfluidic control system is necessary with an effective fluid

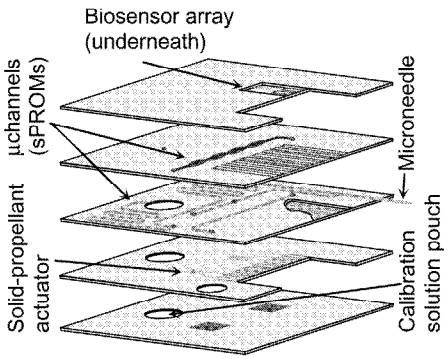

Figure 1. Schematic sketch of disposable plastic biochip.

[1] The details of the sensor operation are presented in "Development of inexpensive biosensor array for point-of-care testing" in these proceedings.

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propulsion system. We have developed the *structurally programmable microfluidic system* (sPROMs) for passive microfluidic control and an innovative solid-propellant based fluid driving system. The solid-propellant approach coupled with the sPROMs microfluidic system allows for precise, low power microfluidic sequencing. Figure 1 shows a schematic sketch of the disposable biochip with the integrated sensor array for multi-analyte detection.

DISPOSABLE PLASTIC BIOCHIP

Structurally Programmable Microfluidic System

We have previously reported the development of a smart, passive microfluidic control technique, which we call sPROMs [1,2]. sPROMs relies on the physical dimensions and surface properties of the microfluidic channels to regulate microfluidic sequencing. We have developed and characterized a microfluidic dispenser for sub-μL volume dispensing and have successfully integrated with a microfluidic multiplexer for further fluidic sequencing. Figure 2 shows the sequence of operation for the biochip.

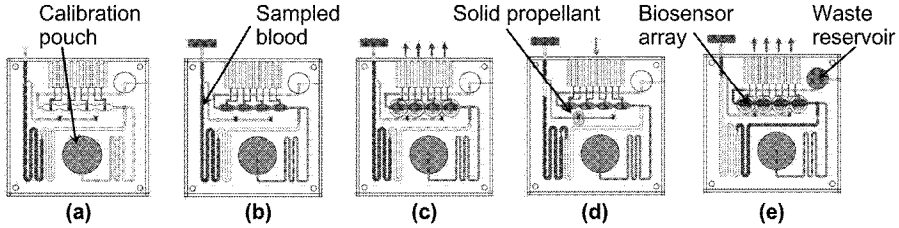

Figure 2. Schematic sketch showing operation sequence of the biochip.

Figure 2 shows the operation sequence of the disposable biochip. Initially, the sample is loaded using the integrated needle. Then the biochip is inserted into a custom designed socket, which simultaneously seals the needle and also applies pressure on the on-chip calibration pouch via a flexible bottom layer. The applied pressure ruptures the pouch and the calibration solution flows out to fill the sensor chamber. The calibration solution contains analytes with known concentrations and is used to calibrate the biosensors at the given environmental conditions. Figure 2(d) shows the solid-propellant actuation by applying a heat pulse. The air-pressure from the solid-propellant dispenses a precisely metered volume of the sample to the sensor chamber for measuring clinically relevant parameters.

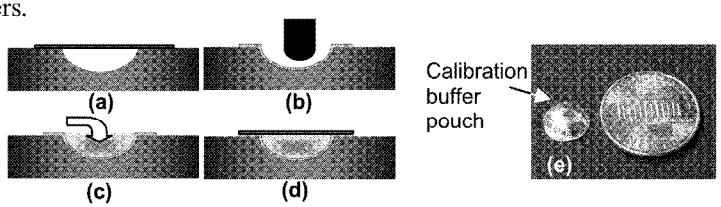

Figure 3. Calibration pouch: (a);(b) forming of aluminum foil over molding cavity; (c) fill calibration solution; (d) seal with adhesive lined metal tape; and (e) fabricated device.

Figure 3 shows the assembly sequence for the metallic calibration pouch. A metallic pouch is used in this application to minimize the diffusion of gases to and from the environment that might alter the known concentrations of the calibration buffer.

On-Chip Functional Pressure Generator Using Solid Propellant

The functional pressure generator consists of a solid chemical propellant positioned on a microheater. The solid propellant (AIBN - azobis-isobutyronitrile) decomposes at 70 °C and releases non-toxic Nitrogen gas a by-product as shown in Figure 4 [3].

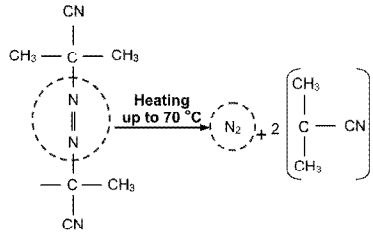

Figure 4. AIBN decomposition mechanism.

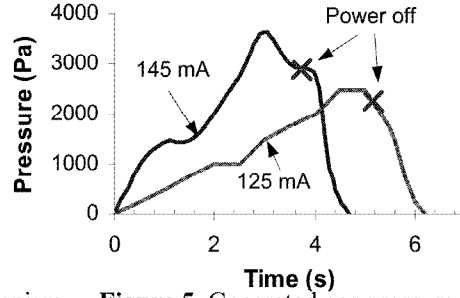

Figure 5. Generated gas pressure as a function of applied power.

This device can be easily integrated with the biochip using standard lithography/screen-printing techniques. The amount of Nitrogen generated is governed by the applied thermal power and can be easily regulated. Due to its compact size, easy fabrication, easy integration, high reliability, biologically inert gas output, and functionality of gas generation, this pressure generator serves as an excellent driving mechanism for the biochip application. Figure 5 shows the dynamic pressure response of the solid-propellant actuator clearly demonstrating the controlled pressure release characteristics.

HANDHELD ANALYZER

Figure 6 shows the handheld analyzer used with the biochip. The packaged analyzer is only 5.25"X3.25"X1.25" in size. The analyzer has SMT (surface mount technology) based electronics system, batteries, display and control switches. The batteries shown in Figure 6 are capable of running the analyzer for over 100 consecutive tests.

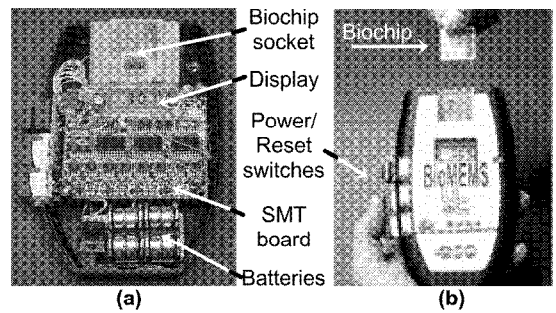

Figure 6. Handheld analyzer: (a) open view and (b) packaged analyzer with biochip.

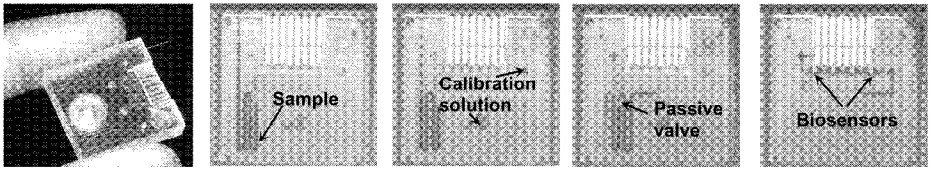

Figure 7. Fully integrated disposable biochip (a) microphotograph of actual biochip; (b) – (d) microfluidic sequencing of biochip exactly corresponding to Figure 2.

RESULTS

Figure 7 shows an actual biochip which is only 1"X1"X0.25" in dimension fabricated using plastic micromachining techniques [4]. The microfluidic operation sequence of the biochip is shown in Figures 7(b)-(d) and clearly show that the biochip can perform the desired the microfluidic sequencing. Figure 8 shows a representative measurement from the biosensor array [5]. The measurement result is obtained from actual human blood sample and clearly demonstrates the linearity of the sensor. The biosensor array also simultaneously monitors lactate and oxygen concentrations from human blood samples.

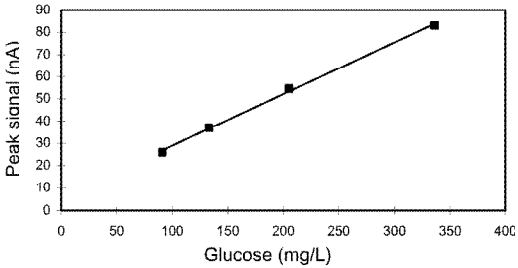

Figure 8. Glucose measurement results from human blood using disposable biochip.

CONCLUSION

This paper presents a plastic-based, disposable biochip with smart microfluidic control, on-chip pressure generator, and biosensor array. The biochip uses low power (~ 60 mW) for operation and is capable of smart, passive microfluidic control. The biochip also has an on-chip calibration facility to counteract environmental effects such as variations in temperature, thus making it useful for field applications. The disposable biochip with the handheld analyzer has been demonstrated for measurement of clinically relevant parameters from human blood such as *Glucose*, *Lactate* and *Oxygen* and is of immediate relevance for point-of-care health monitoring applications.

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Reference:

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