MEMS Bubble Actuated Valve for Interstitial Glucose Sensing

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The Bio-Fluidic Integrable Transdermal (B-FIT) Microsystem is a miniature chemical analysis system for sampling and detecting glucose in real time (Figure 1). The B-FIT consists of four subsystems, the thermal perforation subsystem (TPS), the microfluidic subsystem (MFS), the patch interface subsystem, and the detection patch subsystem. The micro-heaters situated on the TPS produce tiny micro-pores by thermal ablation of the stratum corneum, which forms the outermost layer of dead skin cells of the skin. This allows diffusion of glucose by perfusion from fluid contained within a reservoir in the B-FIT system. The MFS assists the transporting of glucose to the detection patch subsystem. The electrolysis design in the MFS is to provide the actuation force for rupturing the microreservoir by applying back pressure to a thin membrane. The flow of liquid from the reservoir is perfused over the ablated area, diffusing glucose from the interstitial fluid ,and moving liquid up the capillary by providing pressure from the gas bubbles fomed.

The use of electrolysis of water on the microscale is studied for valve actuation. We have patterned planar noble metal electrodes on transparant glass to investigate different metal material and electrolyte solutions for optimal bubble generation. Deformation of the 45 µm thick SU8 layer is also demonstrated with the electrolysis process. These studies will facilitate further integration of the electrolysis module in the BFIT, and numerous applications are envisioned for microfluidic systems.

As shown in Figure 2, electrolysis is the process of passing an electrical current through a substance in order to produce chemical change in the substance. Since water is composed of oxygen and hydrogen, electrolysis of water generates oxygen and hydrogen gas. The reactions at the electrodes involve changing ions into gases. At the anode, two protons are reduced (gain electrons) and become H_2 gas. At the cathode, two hydroxide ions (OH^-) are oxidized (lose electrons) and become oxygen gas and hydrogen ions.

$$2H^+ + 2e^- \rightarrow H_2 \quad 2OH^- \rightarrow O_2 + 2H^+ + 4e^-$$

Faraday's Law can describe the relationship between electric current and the quantity of gas generated:

$$\frac{dq}{dt} = nFi$$

, where n is number of electrons per molecule of product and F is Faraday's constant, $F=9.6486 * 10^4$ coulombs/mole of electrons.

The amount of charge needed to produce a given size of bubble was determined by the ideal gas law.

$PV = nRT$, where R is universal gas constant
R= 8.3148J/mol*K

The pressure P inside the bubble is proportional to surface tension σ divided by radius of curvature γ.

$$P = \frac{2\sigma}{\gamma}$$

In conventional size fluidic systems, bubbles are not effective actuators because inertial forces are much stronger than surface tension forces. However, the scaling advantages of surface effects allow bubbles to apply significant forces in the microscale. Meanwhile, the density difference between liquids and gases (typically three orders of magnitudes) allows very large expansions and long throw actuations when converting fluid to gas [1].

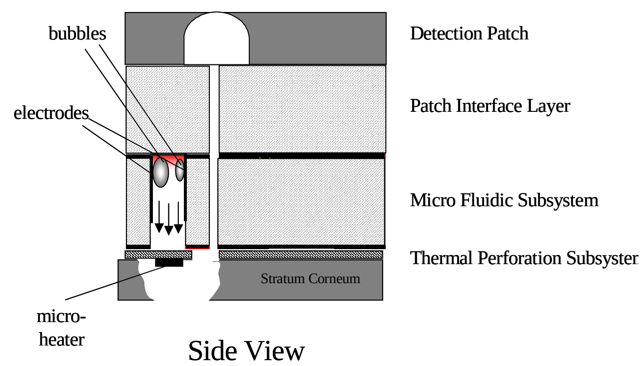

Figure 1. B-FIT Concept showing individual subsystems

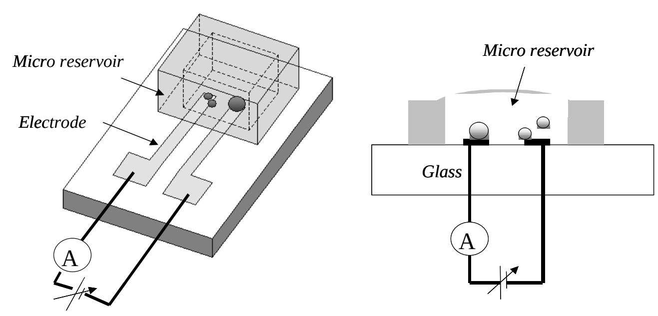

Figure 2 Design of fabricated microelectrodes for electrolysis

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References

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