A PCB integrated actuator employing water electrolysis for use in microfluidic systems

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Abstract

This work concerns the development of a novel actuator based on water electrolysis for use in microfluidic systems. The electrolysis is performed inside a confined micro-reservoir integrated on a PCB substrate which is connected to a microchannel. During the electrolysis process, the generated gases within the enclosed structure lead to a significant pressure increase which can be employed in order to move a liquid inside the microchannel. In order to demonstrate the device’s principle of operation, water is driven through a meander micro-structure which is connected at the output of the micro-tank. Furthermore, the effectiveness of employing electrolysis as an actuating principle has been investigated by monitoring the obtained pressure increase for a device with a larger reservoir; preliminary results are clearly promising.

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1. Introduction

Electrolysis is a well-known process for producing oxygen and hydrogen gases from water; the idea of employing electrolysis as an actuation principle is not new, its main advantages are the low power consumption and minimum heat dissipation. Successful efforts have been reported in the past [1, 2] where substantial pneumatic energy was obtained by performing electrolysis of water in a confined space.

In the current work, an actuator for microfluidic systems whose operation is based on the electrolysis of water is presented. The device is mainly comprised of a reservoir in series with an appropriate microchannel. The principle of operation of the proposed device is as follows: Applying a given voltage to appropriate integrated electrodes inside the reservoir, results to the electrolysis of the contained electrolyte - therefore, to the formation of hydrogen and oxygen gases. By controlling the applied
voltage/current and its duration, one can effectively control the rate and the duration of the gas formation, responsible for the built-up pneumatic energy inside the reservoir. Due to the pressure increase which is developed at the inlet of the microchannel, the contained liquid is forced to move.

2. Experimental results

In order to demonstrate the use of water electrolysis as an actuating principle for microfluidic systems, an appropriate device was initially constructed (fig. 1.a). The device is comprised of a micro-tank in series with an appropriate microchannel. The two opposite sides of the micro-tank comprise also the electrodes, necessary for the electrolysis process (fig. 1.b). Both the micro-tank walls and the microchannel walls consist of Cu tracks of appropriately formatted PCB surface; in this way direct electrical communication to the macroworld is available. Sealing of the formed microstructures is performed via employing specialized polyolefin sealing tape (fig.2.a)-the formation technology employed for the device has been presented previously [3].

A micro-meander structure is integrated in series with the micro-tank in order to demonstrate the device’s operation. Applying appropriate voltage/current between the two electrodes, for a given time.
interval, results to consequent movement of the liquid inside the micro-meander (fig. 2.b), demonstrating the device’s operation. Thus, we can conclude that a significant pressure increase is present at the micro-tank’s outlet.

![Diagram](image)

Fig. 2. (a) Outline of the fabrication process of the device
(b) Applying appropriate voltage/current between the two electrodes results to consequent movement of the liquid inside the micro-meander

2.1. Determining the effectiveness of electrolysis as an actuating principle

Having demonstrated the constructed device’s operation, the effectiveness of employing electrolysis as an actuating principle has been investigated. In more detail, a device with a larger reservoir (volume capacity of 1 ml) has been constructed and the resulting pressure increase during its operation has been measured directly at the outflow of the reservoir. We should note that having a larger tank results to a significant increment of the volume of the contained electrolyte; thus, to a consequent increase of the resulting pressure during electrolysis.

The reservoir of the device has been formed by mounting a Plexiglas structure directly on the PCB substrate. Note that the necessary electrodes have been integrated on PCB prior to the adhesion. A top-view of the device is presented in fig. (3). Impletion of the reservoir with electrolyte is performed through an appropriate inlet situated on the top side - sealed during the electrolysis process. A commercial pressure sensor (9510U by Spectre Sensors) has been employed in order to monitor the resulting pressure increase during electrolysis.

The built-up pressure measured at the outlet of the reservoir during operation of the device is presented in figure (4). As we can notice the pressure increases continuously with time as expected, due to the constant gas evolution, while the pressure increase rate is constant for a fixed current applied. Increasing
the current value, results to a consequent increment of the pressure increase rate; a 200 mBar pressure build-up was recorded after applying 8 mA for five minutes at the device.

![Fig. 3. Top-view of the device employing a larger reservoir](image)

![Fig. 4. Pressure increase at the outlet of the device vs time](image)

3. Conclusions

A novel actuator based on water electrolysis for use in microfluidic systems has been developed and its principle of operation has been successfully demonstrated. A significant advantage of the proposed device is the simplicity of its fabrication process, which also translates to reduced fabrication cost and time. The effectiveness of employing electrolysis as an actuating principle for microfluidic systems has been investigated also; a large pressure increase occurring at a short time interval has been recorded, clearly suggesting a promising performance for such devices.

References

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