Application of the light-addressable potentiometric sensor to microfluidic devices

T. Yoshinobu[1], Y. Ui[1], H. Iwasaki[1], N. Näther[2], M. J. Schöning[2,3], M. Koudelka-Hep[4]

[1]ISIR, Osaka Univ., Japan
[2]Univ. of Applied Sciences Aachen, Div. Jülich, Germany
[3]ISG-2, Research Centre Jülich, Germany
[4]IMT, Univ. of Neuchatel, Switzerland

Introduction

The light-addressable potentiometric sensor (LAPS) [1] is a semiconductor-based chemical sensor with an electrolyte-insulator-semiconductor (EIS) structure (Fig.1). Under a fixed bias voltage, the ac photocurrent signal varies depending on the ion concentration of the solution (Fig.2). Since the active area on the LAPS surface is defined by illumination, two-dimensional mapping is possible by using a scanning laser beam [2].

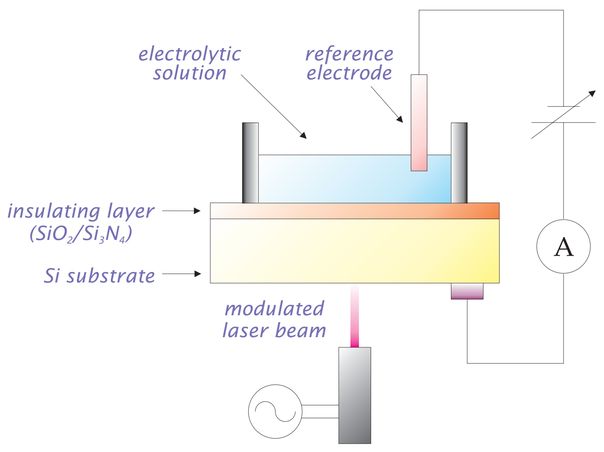


Fig.1 Construction of LAPS.

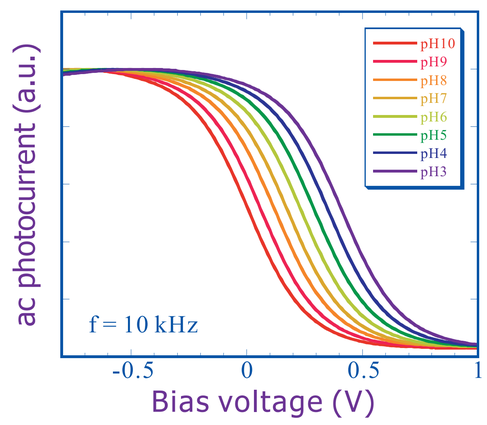


Fig.2 Typical current-voltage characteristics of LAPS.

In this study, the LAPS is applied to chemical imaging of microchannels.

Measurement system

Since the LAPS has no device structures on the sensing surface, any points inside the microchannel become addressable simply by constructing the microfluidic device on the LAPS surface (Fig.3).

Two types of microfluidic devices fabricated with the SU-8 / PDMS technology were tested (Fig.4).

Chemical images are obtained by recording the amplitude of photocurrent while the laser beam scans the sensor (Fig.5).

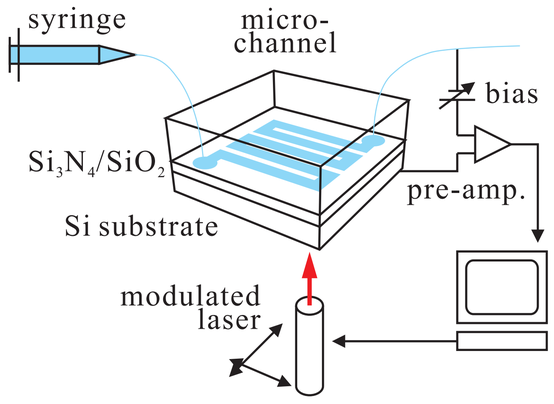
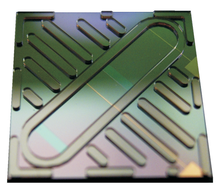
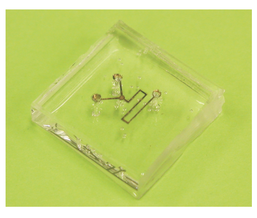


Fig.3 Construction of a microchannel on the sensing surface of LAPS.



(type I)
SU-8 patterns are directly formed on the sensor surface.



(type II)
PDMS block with a channel pattern (to be put on the LAPS surface).

Fig.4 Examples of microchannels.

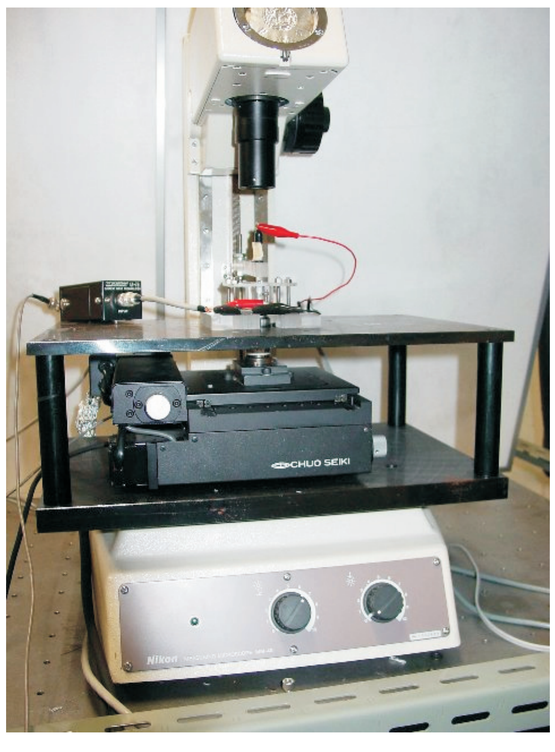


Fig.5 The measurement system with a scanning mechanism.

Results and discussion

Figure 6 shows an example of sequential images, in which injection of the buffer solution is visualized.

(The injection of the buffer solution is interrupted for each measurement, which takes 3 minutes.)

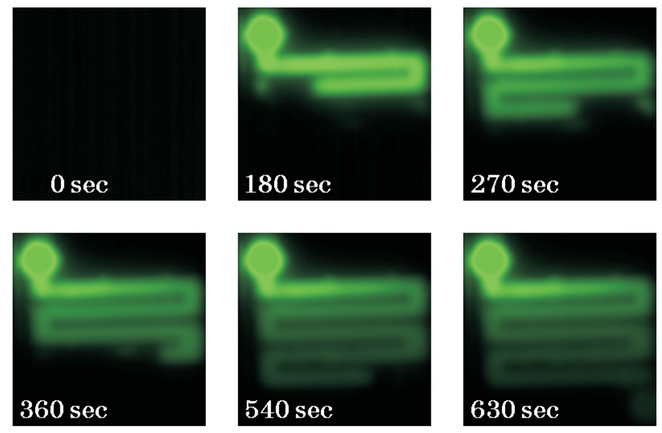
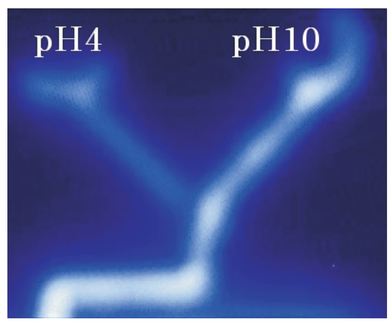


Fig.6 A series of photocurrent images of the microchannel during the injection of pH buffer solution.

As shown in Fig.7(a), the solution with a higher pH value appears brighter in the image, which is consistent with the current-voltage curves in Fig.7(b).

(a)



(b)

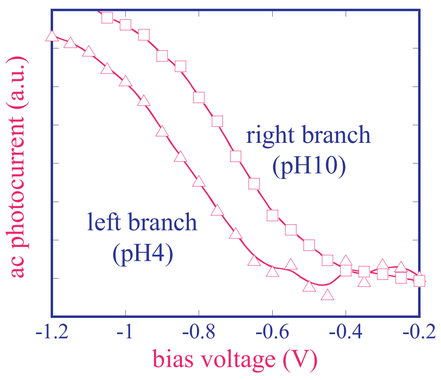


Fig.7 (a) The photocurrent image of the microchannel with two branches filled with pH4 and pH10 buffer solutions. (b) Current-voltage curves for the left branch (pH4) and the right branch (pH10).

At present, the scanning mode is too slow for real-time imaging of the entire channel. It is possible, however, to monitor the pH change only at several points of interest in the microchannel. Figure 8 shows an example, in which the pH change is observed at a fixed point in the microchannel.

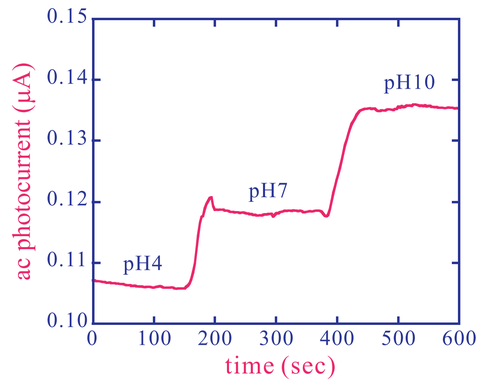


Fig.8 Recording of the pH change at a fixed point in the microchannel.

Development of a high-speed LAPS is expected to realize the real-time imaging of the entire channel of microfluidic devices.

Acknowledgments

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References

[1] D. G. Hafeman et al., "Light-addressable potentiometric sensor for biochemical systems", Science 240 (1988) 1182-1185.
[2] M. Nakao et al., "Scanning-laser-beam semiconductor pH-imaging sensor", Sensors and Actuators B 20 (1994) 119-123.