Characteristics and Fabrication of 2-Dimensional High Speed pH Image LAPSwith the Si_3N_4 and the Ta_2O_5 Sensing Membrane

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1. Introduction

LAPS (Light Addressable Potentiometric Sensor) is a device which can detect pH with surface potential variation based on the location of illuminated light. It is valuable as a sensor for real time observation of chemical process [8].

Therefore, the research on the analysis of micro-organism and penicillin has been reported recently in the application fields such as environments, bio-chemical and radiological measurement of military area, the inspections of foods and water by detecting pH variation occurred by the immunity reaction [1]. But monitoring of linear pH change at the fixed location is unsuitable for the detection of the diffusion speed and distribution of the microorganism. In the recent years, research for detection of the diffusion speed and 2-dimentional distribution occurred by the metabolism of the microorganism and cell has been focused. However, such sensors suffer from the problem of the resolution and analysis time [2].

In this paper, we proposed the high speed image LAPS and did the fundamental research for the measurement a real time diffusion and distribution of the micro-organism [5, 6]. The image detection system was designed by LABVIEW. We investigated the basic characteristics of image biosensors with high resolution and sensitivity. The applicability and usefulness as a biosensor were examined.

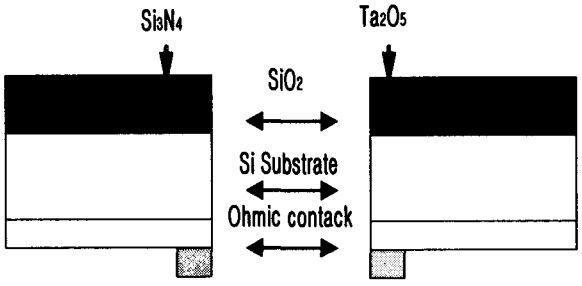


Fig. 1. The structure of LAPS.

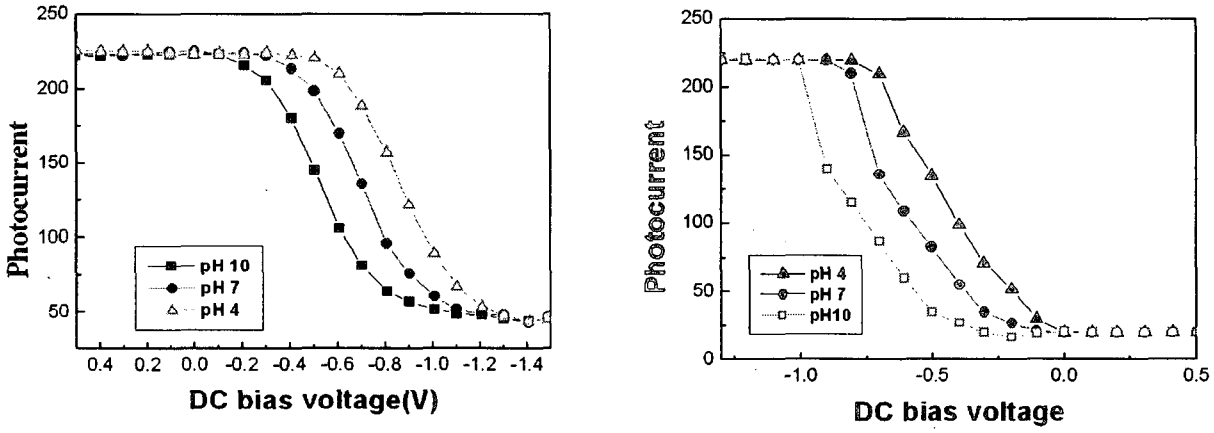
First of all, LAPS was fabricated respectively. The LAPS chip size was 2 cm × 2 cm and

sensing gate area was 1 cmx1 cm. The gate oxide was grown about 300 Å by dry oxidation. To get the optimum sensing characteristics of the pH image LAPS, Si_3N_4 (about 800Å) and Ta_2O_5 (about 800 Å) films were deposited by LPCVD [3] and RF magnetron sputtering as hydrogen ion sensing membrane respectively. Computer simulations were also executed to get the best condition of device and more suitable signal processing system. Fig.1 shows the structure of fabricated LAPS.

2. The principle of Image LAPS

The best known characteristic of LAPS is to show responses at the illuminated point. By using this fact, when alternative light of regular frequency is illuminated into the LAPS device or in the rear surface of the Si substrate and DC voltage is applied into the electrolyte, the DC bias voltage forms the inversion layer in the LAPS device and then the charges in the inversion and insulator layer are modulated by the electron-hole pair to make the AC photocurrent [1, 4, 7]. If DC bias voltage forms the accumulation state, there is no photocurrent because of absence of electric field on the surface of silicon. Therefore, the curve of AC photocurrent versus DC bias voltage shows large changes between accumulation state of no photocurrent and inversion state of maximum photocurrent [4].

From this result, photocurrent which was generated by applied DC bias voltage shifts according to pH variation because of surface potential change. A two kind of the fabricated sensing membrane was compared about photocurrent which was generated by pH variation. Sensitivity of .Si_3N_4 and Ta_2O_5 were about 55 mV / pH, 58 mV / pH respectively. Fig. 2 shows movement curves of photocurrent according to various pH values.



(a) (b)

Fig. 2 (a) pH vs. photocurrent curve (Si_3N_4) and (b) pH vs. photocurrent curve (Ta_2O_5)

In earlier study, to apply a pH-image sensor, a focused laser beam is used as light source but it takes very long time to measure photocurrent at the accurate position. Such reason is that 128 x 128 = 16, 384 pixels is large number of pixels.

In this paper, however, we propose the line-scanning method for fast image. While the laser beam is scanning 1 line at a sensing area of the LAPS, LAPS system is sampling at the fixed and applied DC bias voltage. The sampling frequency is 12 ms, the total time of 1 line scanning is 1.5 sec. As shown in Fig. 3, we fixed DC bias voltage and the generated photocurrent was measured at pixels respectively. Our system with LAPS device get data about 128 x 128 pixels without delaying, the data acquisition time was 3min in total.

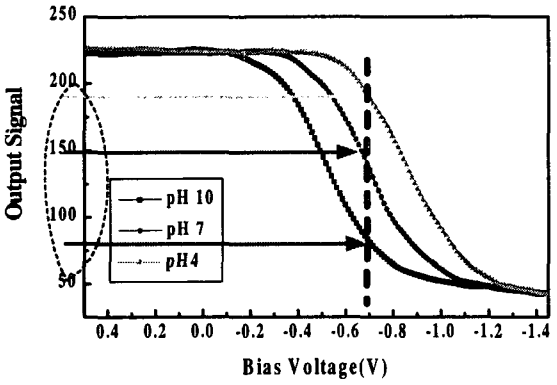


Fig. 3. The detect method of Image at a fixed bias voltage.

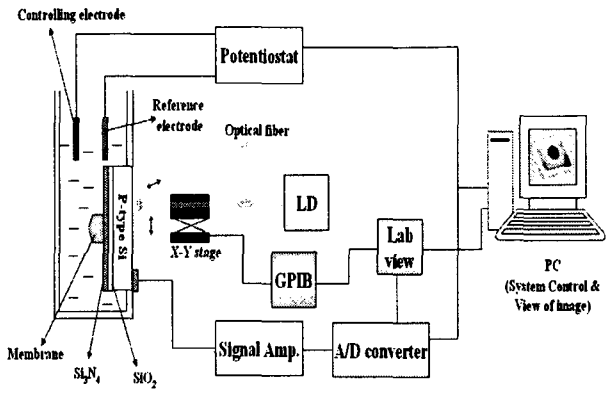


Fig. 4. The Schematic of pH-imaging LAPS system.

3. Experimental and Results

To apply chemical-imaging sensor and bio-imaging sensor, we investigated the characteristics of fabricated sensors. In this study, the high speed image LAPS which can detect the diffusion speed and concentration form of the microorganism was fabricated. Our system was composed of x-y linear stage (Suruga Seiki) for the micro-control of the illuminated light source (830nm, pigtailed LD, ThorLabs) and LABVIEW (National instrument) to get and modify data. The LAPS device formed a star shape pattern on the sensing membrane by using photolithograph method. The advantage of this LABVIEW(Laboratory Virtual Instrument Engineering Workbench) is that the alteration of acquired data is possible by using graphical program, which has easy control than code based program dose. In the previous studies, LAPS system had complexity like optical part, micro-control linear moving stage and signal processing part (Lock in amp, pre-amplifier etc...). But our system is simple, LABVIEW makes it possible to process the acquisition data fast.

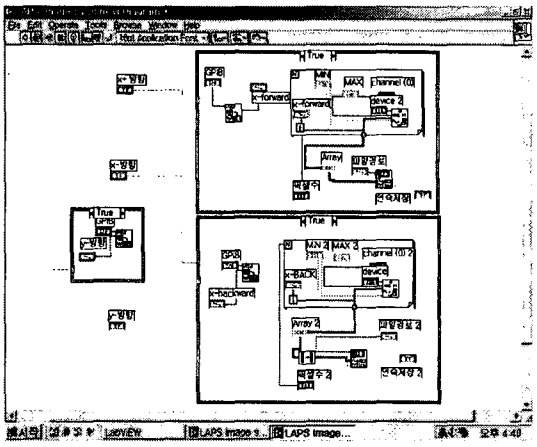


Fig. 5. The Block Diagram to acquire data And control motor Software.

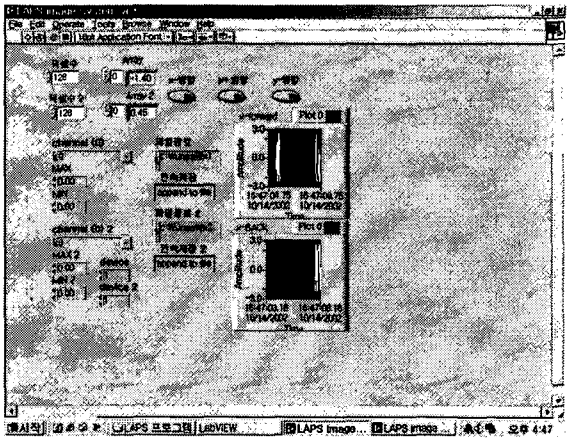


Fig. 6. The Front Panel of LABVIEW Software.

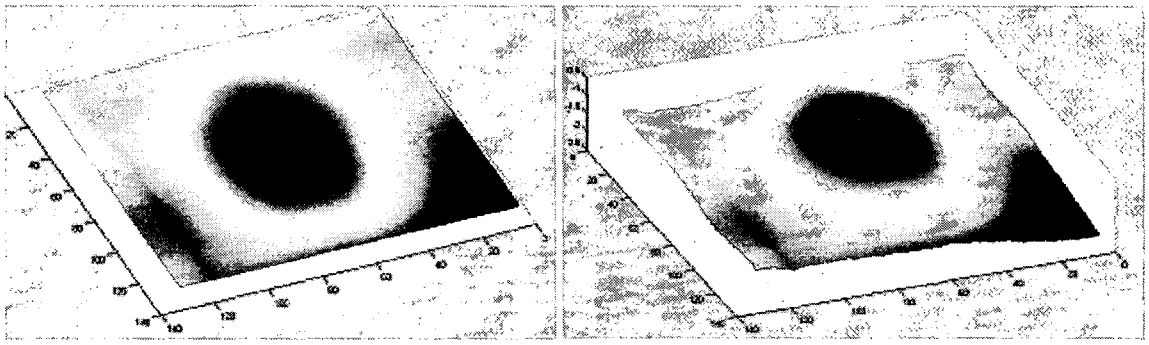


Fig.7. 2,3-dimentional image of 128 × 128 pixels.

The implemented system was shown in Fig. 4. Fig. 5 and 6 show LABVIEW software program. As a result of those, the acquired data were arranged for 2-dimenional array by LABVIEW. Fig. 7 was the result of the 2, 3-dimensional image. It had high resolution, high sensitivity and high speed. It was shown fast response than the previous LAPS system did. To image 128 × 128 pixels, it takes about 3min in total.

4. Conclusions

In this study, Si_3N_4 and Ta_2O_5 sensing membrane were investigated as an imaging sensor, the LAPS image sensor has been used for fundamental research that can detect the cell distribution or diffusion speed. Si_3N_4 thin film was deposited by LPCVD and its pH sensitivity was 55mV / pH.

Also, Ta_2O_5 thin film was deposited by RF magnetron sputtering and its pH sensitivity was 58 mV / pH. First of all, this paper showed Si_3N_4 LAPS to apply imaging biosensor or imaging chemical sensor. To image 128 × 128 pixels, the implemented system has high speed and high resolution. We proposed the line-scanning sampling method for high speed. It is possible to observe metabolism of penicillin, microorganism and cells as a real time.

Therefore, it can be used on commercial business about the part of biochemistry or Medical & Biological Engineering.

In further work, Ta_2O_5 LAPS will be investigated about 128 × 128 pixels or 256 × 256 pixels, and will be observed growth of penicillin and cells which culture on the Si_3N_4 and Ta_2O_5 sensing membrane respectively.

Acknowledgments

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