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A Friendly Portable 2D Chemical Imaging System

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Abstract

A miniaturized and synchronized readout system of light-addressable potentiometric sensor (LAPS) for portable application is introduced in this report. A field-programmable gate array (FPGA) board and a self-designed circuit board are used to integrate the functions of function-generator, pre-amplifier, lock-in-amplifier and DAQ card, which can be controlled by a self-designed LabVIEW program synchronously. Real-time two dimensional (2D) chemical images can be easily collected by this system with advantages of small size, low cost, friendly usage and zoom-in function.

1. Introduction

2D chemical imaging is an interesting topic for biology and chemistry [1]. Fast scanning LAPS systems based on OLED [2] and multi-channel optical fiber [3] are proposed for 2D imaging. However, there are still some limitations need to be improved including signal-to-noise ratio, synchronization and complexity An IR-laser combined an analog micro-mirror scanning system can provide the fastest scanning speed of single light source and high signal-to-noise ratio, which was demonstrated by our group in the previous study [4]. However, none of these systems is able to be used for home care product or clinical medical application results from high price, large size and complicated operation.

A novel system based on a commercial FPGA board and a self-designed PCB is proposed with self-designed LabVIEW program as synchronously control interface. pH response and real-time 2D imaging is also presented.

2. *Experiment*

The miniaturized system is composed of a commercial FPGA board sbRIO-9636 from National Instruments Corporation, a self-designed control board, an IR laser, an analog micro-mirror, and a reference electrode. Fig. 1(a) shows the original micro-mirror based LAPS system and Fig. 1(b) shows the miniaturized system in this study. Total volume is reduced significantly as shown in Fig. 1(a) and 1(b) with the same scale.

Square signal with adjustable frequency can be generated for the laser. Configurable step bias can be provided to the reference electrode with tunable increment of step, delay time, minimum and maximum output. To define the scanning area or detection point, the sbRIO-9636 is used to set variable X/Y-amplitude and X/Y-offset by the three dimensional deflection angle of micro-mirror. The amplified and filtered photo-voltages are recorded to their coordinates in X and Y axis synchronously. LAPS samples are fabricated with Si_3N_4 and SiO_2 on the top of P-type Si wafer [4].

3. Results and discussion

To have higher signal for faster frequency, the optimal frequency for sample needs to be confirmed. Fig. 2 shows the measured photo-voltage versus bias voltage by different frequency. Photo-voltage in inversion region increases with provided frequency to the maximum at 11 KHz. After that, photo-voltage decreases as frequency increases. There is no response when frequency is higher than 20 kHz in current

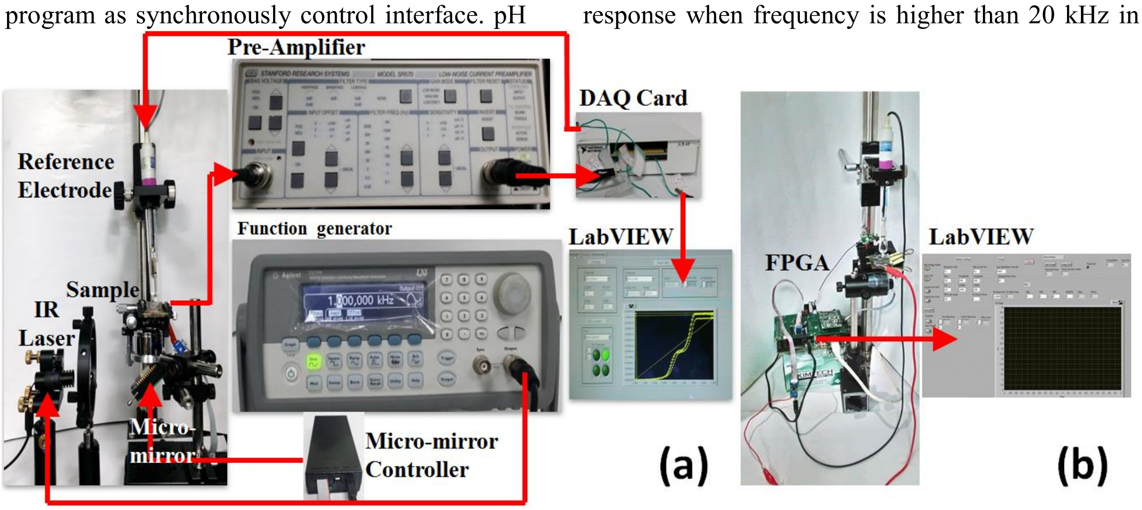

Fig. 1 (a) original micro-mirror based LAPS system and (b) the miniaturized system.

setting. The pH sensing performance is tested at the frequency of 11 kHz in different pH solution as shown in Fig. 3. The photo-voltage to bias voltage curve shifts to positive voltage with the increase of pH of the solution. pH sensitivity of 54.78 mV/pH with linearity of 99.65% is obtained by the linear fitting of this curve as shown in Fig. 3.

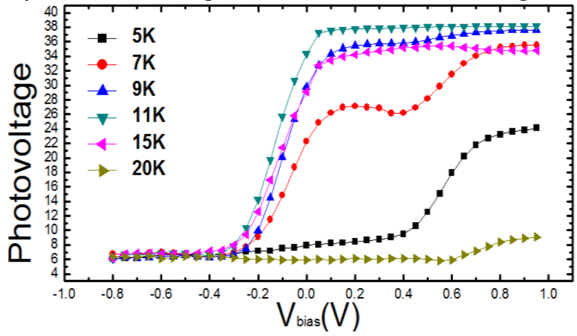

Fig. 2 Frequency dependent photo-voltage versus bias voltage of Si_3N_4/SiO_2-LAPS in pH 7 solution.

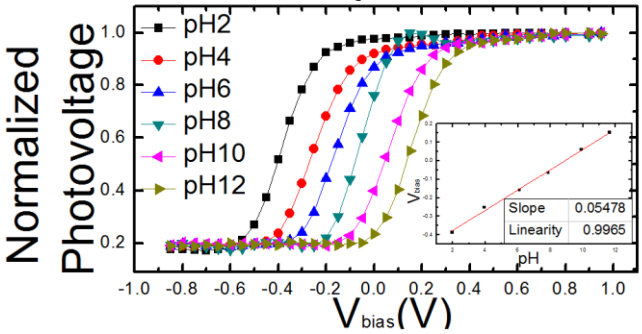

Fig. 3 Normalized photocurrent versus bias voltage curve of Si_3N_4/SiO_2-LAPS in different pH solution.

With the combination of photo-voltage and its coordinates, the 2D image can be generated easily with a built-in Matlab program in the LabVIEW project. For a 2D image with a resolution of 500×500 pixels can be generated within 7 minutes. The process time of 1 frame can be calculated easily by the following equation:

$$T = P \times Rows \times Cows \div F \qquad (1)$$

where T is the time of pixel image generation, P is the data processing period per pixel. Rows and Cows is the pixel number in the X and Y-axis. F is the modulated frequency provided to the IR laser.

A LAPS sample with an "O" pattern defined by epoxy is used to check chemical images generated by this system. Chemical images with resolution of 500×500 pixels in buffer solutions of pH 4, pH 7 and pH 10 with bias voltage of -0.1V are shown in Fig. 4(b), (c) and (d), respectively. Dynamic imaging with fast scanning can be obtained by decreasing the pixels of 2D image. With the parameters set as *P*=8, *Rows*=15, *Cols*=15 and *F*=11000, 5 images per second can be obtained. RO water of 4 ml is used as background solution. After dripping HCl (pH4) solution of 1 ml into RO water, the gradual photovoltage changes in color level can be detected by time as shown in Fig. 5. The scanning area is set at the lower left quarter of the O pattern to show the boundary of sensing area and the non-sensing area which is blue color in upper right of the image.

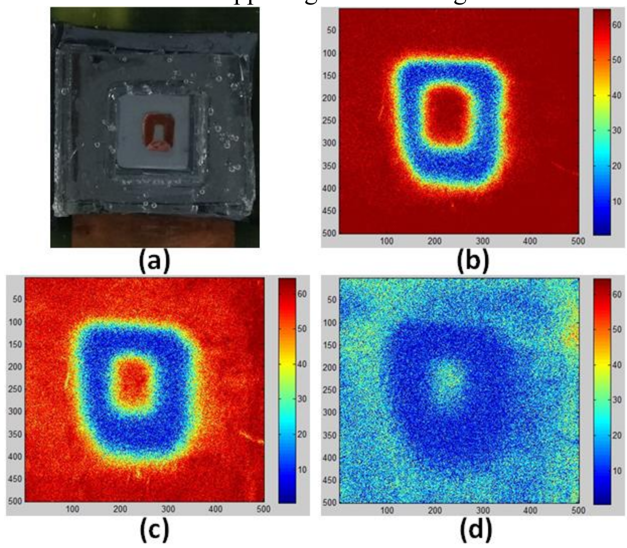

Fig. 4 Sample with O pattern (a) and its statics image in (b) pH 4, (c) pH 7, and (d) pH 10 solution.

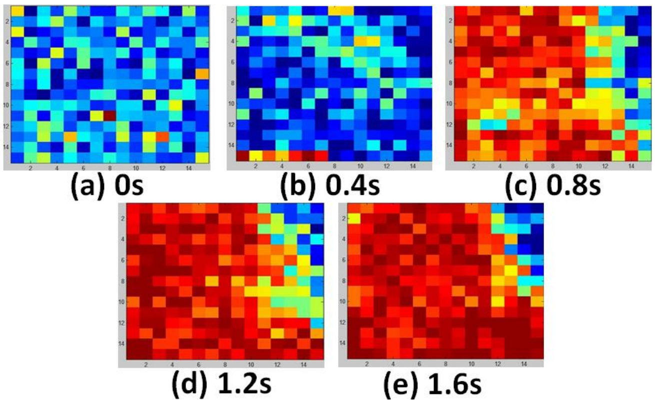

Fig. 5 The dynamic imaging caught after dripping HCl (pH4) solution into RO wafer by different time from (a) to (e).

3. Conclusions

A miniaturized and synchronized LAPS readout system is demonstrated. Frequency effect and pH sensing performance are presented successfully. Real-time 2D static and dynamic pH images are easily realized by this novel and friendly system which can be further applied into home-care and clinic testing.

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