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Improvement of spatial resolution for 2D chemical images in thin-Si substrate

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Abstract

A thin Si substrate with thickness of 200 μm is fabricated by KOH wet etching to study the spatial resolution of 2D chemical image. Scanning procedure is controlled by an X-Y stage with a self-developed LabVIEW program. Spatial resolution is about 50 μm in current setting, which could be further improved by spot size minimization.

1. Introduction

Field-effect sensor is proposed in 1970, which is one of the well-proven ion sensing platforms. [1] To collect data for multi points or species, sensor array is necessary. Light-addressable potentiometric sensor (LAPS) is presented with the combination of the basic field-effect device structure and light addressable scanning methodology. [2] Chemical concentration could be only measured with certain bias and illumination with ac signal modulation. [3] The sensing area could be confined in the light spot area. With light scanning procedure, chemical concentration could be obtained and transferred into 2-dimensional (2D) images. [4] To have a high-resolution image for microfluidics and cell activities, spatial resolution of 2-dimensional image is an important performance index. [5] Spatial resolution could be determined by substrate thickness, doping concentration and wavelength of illumination [6]. In this study, thin-Si substrate was fabricated by designed patterns and KOH wet etching for spatial resolution investigation.

2. Experimental

As shown in Fig. 1, detail process flow is illustrated. 350 um-thick P-type silicon wafers are used as the substrate of LAPS. Thermal oxide (SiO_2) with thickness of 50 nm was grown after standard RCA cleaning. Silicon nitride (Si_3N_4) was deposited by low-pressure chemical vapor deposition (LPCVD). Designed patterns on backside of substrate generated by photolithography and reactive-ion etching (RIE). KOH wet etching operated at 80°C was used to etch Si wafer to remain thickness of 200 μm which was check by alpha stepper. Then remained Si_3N_4 and SiO_2 layers in the backside were all removed by RIE. After buffer oxide etchant (BOE) and distill (DI) water clean, Al layer with thickness of 500 nm was deposited by thermal evaporation. Then patterns with design line width and spacing were generated with self-design mask and SU8-2005 negative photo epoxy by standard photolithography. After packaged by PDMS tank and print circuit board (PCB) on this thin-Si LAPS samples, basic sensing characteristics could be measured by means of standard Ag/AgCl reference electrode, buffer solutions, and electrical instruments [7]. Picture of this fabricated device is shown in Fig. 1(b). With the self-design LabVIEW program controlling x-y stage for sample movement, a precise coordinate of light scanning could be obtained to combine with corresponding photoresponse. Therefore spatial resolution could be easily checked by single line scanning with different measurement setting.

3. Results and Discussion

A high photovoltage could be observed in thin Si substrate as shown in Fig. 2, especially in high frequency. Photovoltage is 4-fold higher in 200 μm-thick Si than 350 μm at 1 kHz. Photovoltage of 200 μm-thick Si LAPS measured at 20 kHz is only a bit higher than 350 μm-thick Si measured at 1 kHz. It would be benefit for high-speed scanning results from high signal-to-noise ratio. pH response of LAPS with different Si thickness are shown in Fig. 3(a) and (b). pH sensitivity and linearity are all higher than 45 mV/pH and 99.7%, which is an acceptable performance for sensing membrane. In the meantime, 2D image could be collected by LabVIEW program with control of X-Y stage in LAPS scanning. With the photovoltage recorded with distance, the response measured with different step spacing is shown in Fig. 4(a) and (b) for different Si thickness. With differential photovoltage versus distance, pattern could be recognized by the distance between the maximum and minimum value. It can be clearly seen spacing of 100 μm is not good for spatial resolution. 10 μm could be a potential candidate with good spatial resolution. Only 800 μm spacing could be seen in 350 μm-thick LAPS. One pattern with width of 200 μm can be measured as 250 μm by means of distance maximum and minimum of differential photovoltage as shown in Fig. 4(c) and (d). Spatial resolution is about 25 μm in one side of pattern. As shown in Fig. 5, chemical images of 200 μm–thick LAPS could be seen clearly. Current results could be further improved by using smaller spot size of red laser.

4. Conclusions

A study on the spatial resolution of Si-based LAPS is demonstrated by modification of thickness of Si using KOH wet etching. High photoresponse and high operation frequency could be the advantages of this proposed device structure. Spatial resolution is about 50 μm with scanning step of 10 μm and laser spot with diameter of 200 μm, which could be improved by smaller laser spot size and the thinner substrate in the future.

References

[1] P. Bergveld, Sens. Actuators B Chem., 88, (1) 1-20, 2003.
[2] M. J. Schöning, Sensors, 5, (3) 126-138, 2005.
[3] D. G. Hafeman, et al., Science, 240, (4856), 1182-1185, 1988.
[4] M. Nakao, et al., Sens. Actuators B Chem., 20, (2-3), 119-123, 1994.
[5] H. Yu, et al., Biosens. Bioelectron., 26, (6), 2822-2827, 2011.
[6] Y. Guo, et al., Sens. Actuators B Chem., 204, 659-665, 2014.
[7] C.-M. Yang, et. al, Sens. Actuators B Chem., 236, 1005-1010, 2016.

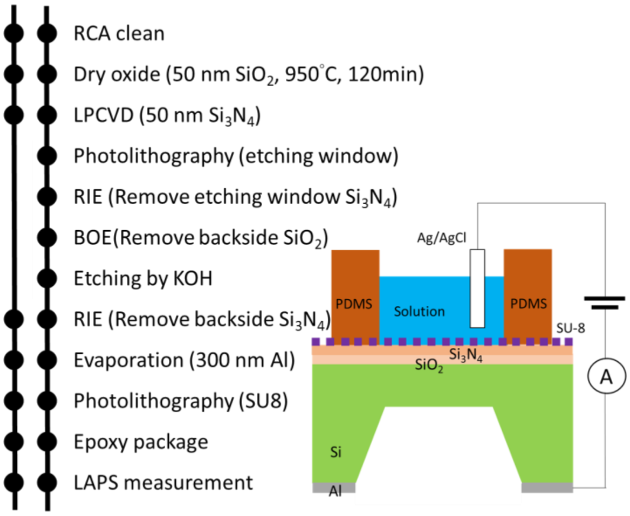


Fig. 1 (a) process flow and (b) picture of this proposed thin-Si LAPS.

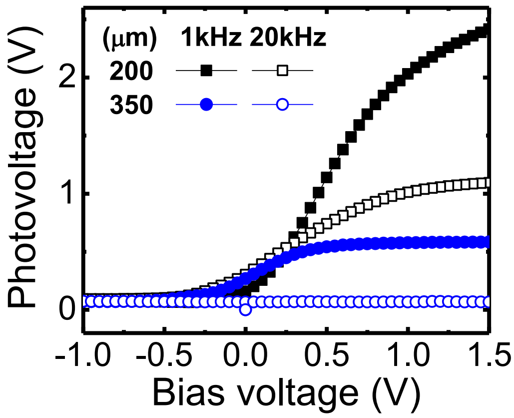
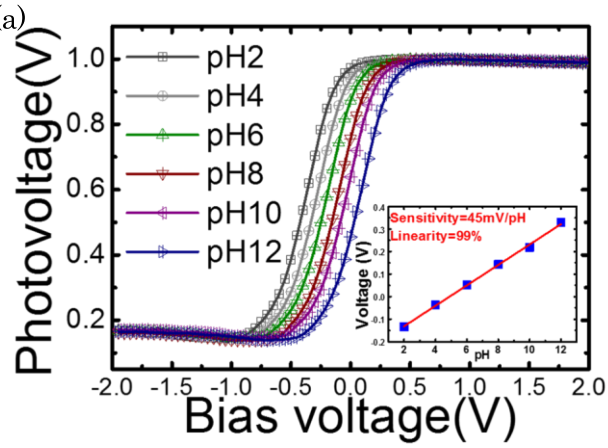


Fig. 2 Frequency response of Si LAPS with difference thickness.

(a)



(b)

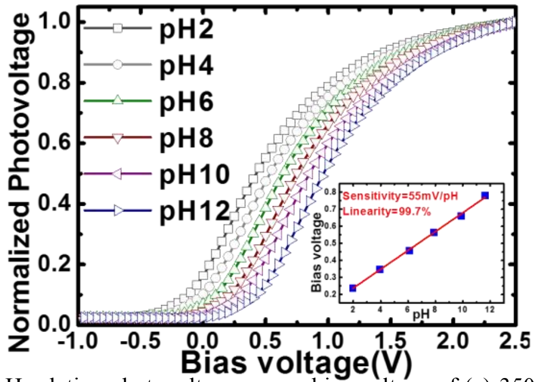


Fig. 3 pH relative photovoltage versus bias voltage of (a) 350 and (b) 200 μm-thick Si-LAPS. Inset of (a) and (b) shows the pH sensitivity and linearity fitting by output voltage and pH value.

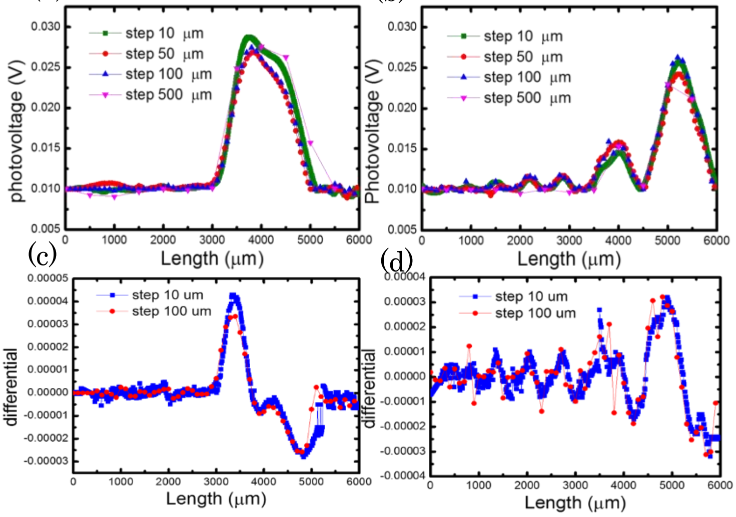
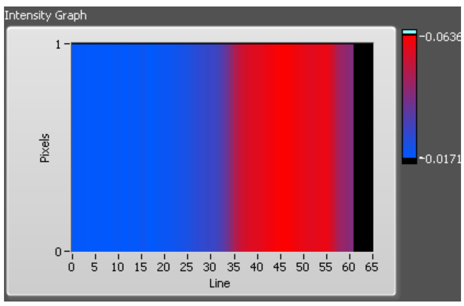


Fig. 4 Photovoltage versus distance for (a) 350 μm and (b) 200μm, differential photovoltage versus distance curves for (c) 350 μm and (d) 200 μm by different step spacing controlled by X-Y stage.

(a)



(b)

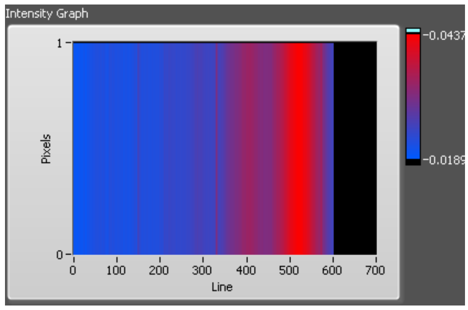


Fig. 5 Chemical image generated by photovoltage of (a) 350 and (b) 200 μm-thick LAPS.