High photocurrent and high frequency response of light-addressable potentiometric sensor with thin Si substrate and surface roughness

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***Abstract*—For two dimensional (2D) chemical images by light-addressable potentiometric sensor (LAPS), high photocurrent obtained in high ac frequency is the most critical criterion to have an acceptable signal-to-noise ratio in a very short time for a pixel. A simple KOH etch can be used to decrease the thickness of silicon substrate for high photocurrent. In the meantime, higher surface roughness in both sides could be achieved by etching flat surface, which is also benefit for high photocurrent and pH sensitivity for rough back and front side, respectively. With this 175μm-thick Si substrate, operating at 20 kHz could be used to collect 2D chemical images easily.**

Keywords*—*LAPS, photocurrent, frequency, thin Si substrate

I. INTRODUCTION

Light addressable potentiometric sensor (LAPS) is an important label free device for a two dimensional distribution of chemical species detection proposed by Hafeman in 1988 [1]. LAPS works with a modulated light source which can be used to scan the sensing area to obtain photo voltage distribution for 2 dimensional chemical image on the sensing surface [2]. To have a 2D chemical image with high spatial resolution (~1 μm) in a short time (<1 sec), ac signal of light source worked in a high frequency and corresponding high output photocurrent are required. Thin Si substrate [3] or amorphous Si (α-Si) [4] in LAPS were both demonstrated with better spatial resolution. However the process and cost are much complex and higher than conventional Si substrate. Therefore Si wafer with a thicknesses of 500 μm and 175 μm by KOH etching back were used to investigate the LAPS response by frequency effect in red laser and chemical image ability.

II. EXPERIMENTAL

As shown in Fig. 1(a), the detail process flow of Si_3N_4-LAPS samples is presented. P-type (100) silicon wafers with thickness of 500 and 350 μm were both used to grow thermal dry oxide (SiO_2) with thickness of 30 nm. A Si_3N_4 layer deposited by low pressure chemical vapor deposition (LPCVD) is used as hard mask during KOH etching and sensing membrane in the front side of silicon wafer. Square patterns as opening area in the backside for thinner Si substrate was defined by standard photolithography process. Then Si_3N_4 and SiO_2 layer in the backside were removed by reactive ion etch (RIE) and buffer oxide etchant (BOE), respectively. To have a thinner Si substrate, patterned Si wafers with thickness of 350 μm were immersed into 20% KOH solution at 80°C to have anisotropical etch. Remain thickness could be controlled by etch time and fixed etching rate of KOH. For the red laser illumination and scanning from LAPS backside, the backside contact of Al layer was opened with an area of 1.2 cm* 1.4 cm by using shadow metal mask with similar pattern of opening area. Then additional encapsulation of PDMS tank was attached to top surface of LAPS chip. In the setup of LAPS measurement, the photosignal from the LAPS was measured by a low-noise current amplifier (SR570, Stanford Research Systems, USA). Photocurrent signal of LAPS can be amplified, filtered and converted to an output voltage signal. Then this amplified output voltage signal was collected and recorded by DAQ card setting and self-developed LabVIEW program. Detail measurement setup of LAPS was presented in on previous literatures. [5]

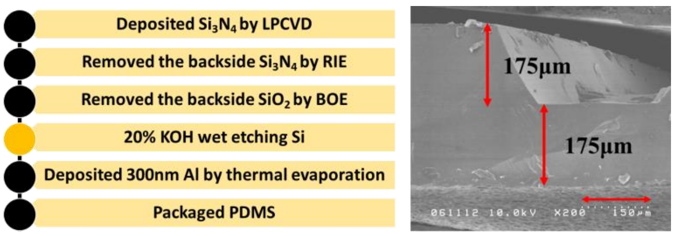

Fig. 1. (a) Process flow of all experimental group and (b) SEM picture.

III. RESULTS AND DISCUSSION

Si substrate with thickness of 175 μm is obtained as shown in Fig. 1(b). Basic pH sensing response of LAPS with Si thickness of 175 μm p-type Si could be seen by photovoltage (PV) versus bias voltage (V) as shown in Fig. 2(a). Higher pH value of buffer solution makes the PV-V curves shift to positive bias, which could be explained by site-binding model and band diagram theory. More negative charges (OH- ions) on

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