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CMOS Optical Polarization Analyzer Chip for μTAS

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1. Introduction

μTAS (micro total analysis system) is expected to be a powerful tool for medical, pharmaceutical, environmental applications [1, 2]. Advantages such as high reaction efficiency and reduction of reactants, time, and costs are expected. We have proposed to implement multifunctional sensors and realized *in situ* monitoring and real time feedback in μTAS [3]. In this work, we develop a polarization analyzing CMOS sensor for μTAS, and demonstrate the basic functionalities of the sensor. We also fabricate a microchamber device equipped with the sensor, and measure optical rotation characteristics with the device.

2. Polarization analyzing CMOS sensor for μTAS

In situ chiral measurement is one of the most expected functions in μTAS. We propose to use a CMOS polarization analyzing sensor for *in situ* chiral measurements in μTAS. When linearly polarized incident light propagates through a solution with chiral reactants, the polarization angle rotates due to the optical activity of the chiral molecules. We demonstrated a CMOS photosensor array for the polarization measurement with monolithically embedded wire grid polarizers formed with a wiring layer in CMOS technology [3]. The fabricated sensor and specifications were shown in the inset of Fig. 1 and Table I. We adopted an active pixel sensor (APS) for the light sensing circuit [4]. We used three photosensors with differently configured on-chip wire grid polarizers; vertical grid, horizontal grid, and without grid as one measurement unit.

3. Microchamber device for polarization analysis

Device design and fabrication

In order to perform polarization measurements of microfluid, we designed a microchamber device equipped with the sensor. The width and height of the microchannel are 600 μm, and 500 μm, respectively, and the dimensions of the microchamber are 1150 μm x 2060 μm x 500 μm. The microchamber structure was configured to cover all the photosensors implemented on the sensor. The fabrication process of the microchamber device is shown in Fig. 2. Firstly, the photoresist mask was patterned on a Si wafer (i). The microchannel and microchamber structure were formed with deep reactive ion etching (DRIE) process (ii). The Si wafer with the microchannel and microchamber structure was bonded with a silica glass cover layer by epoxy resin (iii). The CMOS sensor was bonded on a printed circuit board by epoxy resin and wired with Al wires (iv). The two devices (iii) and (iv) were bonded with epoxy resin (v). The surface of the CMOS sensor was not covered with the epoxy resin. Finally, inlet and outlet ports with aluminum tubes were formed on the device.

Experimetal demonstrations of polarization analysis

We performed polarization measurements in order to evaluate the characteristics of the on-chip grid polarizers and optical rotation measurements of sucrose solutions in the microchamber. The sensor was illuminated with light polarized linearly by a Glan-Thompson prism. We successfully measured the optical rotation angles of sucrose solutions in the microchamber device as shown in Fig. 3. The optical rotation angles with different concentration of the solutions are linearly detected. We investigated the capability of the *in situ* polarization observation. Sucrose solutions with different concentration were sequentially introduced into the device. The sensor output reflecting the temporal concentration change in the solution was successfully observed as shown in Fig. 4. This result shows the polarization measurement sensor is applicable for *in situ* chiral monitoring.

4. A new sensor design

Based on the experimentally confirmed polarization analyzing scheme, we designed a new polarization analyzing sensor. We designed a sensor array composed of 2 x 2 pixel sets with on-chip polarizers with different angles such as; pixel A: θ°, pixel B: $\theta+90^{\circ}$, pixel C: without grid, pixel D: reference. Figure 5 and Table II show the layout and specifications of the new sensor. We can estimate the optical rotation angle from θ when an output of pixel A (and B) becomes minimum (and maximum) with polarized light incident. And we expect better accuracy in measurements by comparing the outputs of pixels in each set; A and B.

5. Conclusions

We have developed the polarization analyzing CMOS sensor for *in situ* chiral measurements in μTAS. Two kinds of polarization analyzing CMOS sensors were designed, and a microchamber device equipped with the sensor was fabricated. We have successfully demonstrated *in situ* polarization measurements using the fabricated microchamber device. The device equipped with the new sensor is fabricated and now under testing.

Acknowledgement

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Table I. Specifications of the CMOS sensor.

Process	0.35 μm 2poly 4metal Standard CMOS
On-chip Polarizer	Line/Space=0.5 μm/0.45 μm (0.95 μm pitch)
Photodiode size	200 μm x 200 μm (3 x 4 array)
Operating Voltage	3.3 V
Chip size	3080 μm x 1880 μm
Readout	Analog Voltage

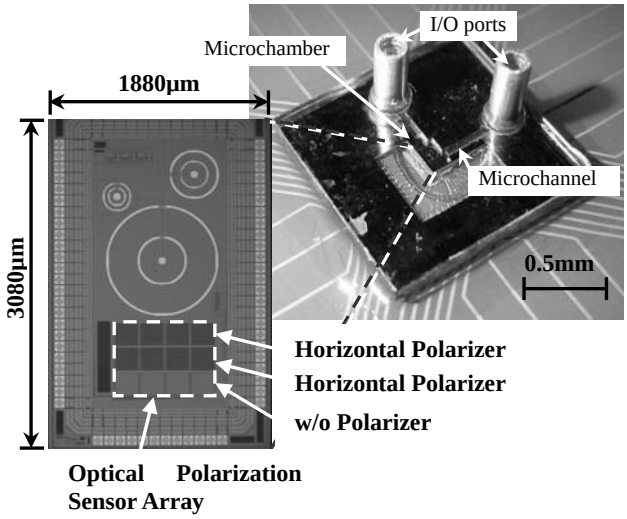

Fig. 1. Microchamber device for *in sutu* polarization measurement and the polarization analyzing CMOS sensor.

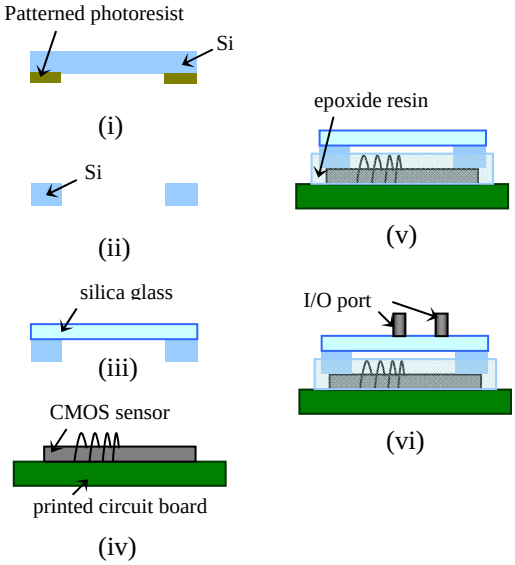

Fig. 2. Fabrication process of the microchamber device. (i) Photolithography , (ii) Deep reactive ion etching, (iii) Bonding a silica glass layer onto the patterned Si wafer, (iv) Bonding and wiring the sensor on a printed circuit board, (v) Bonding the chamber structure and the sensor board, (vi) Inlet/outlet forming.

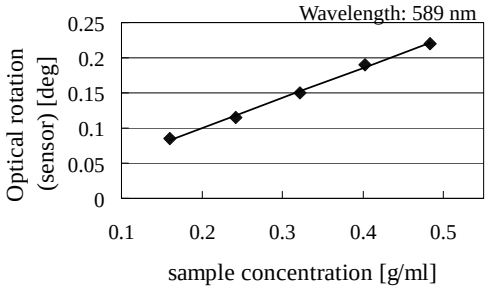

Fig. 3. Optical rotation angles as a function of different concentration of the sucrose solutions.

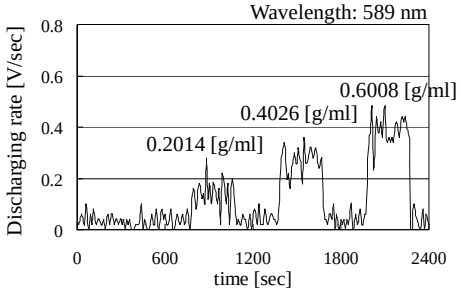

Fig. 4. The sensor outputs reflecting the temporal concentration change in sucrose solution.

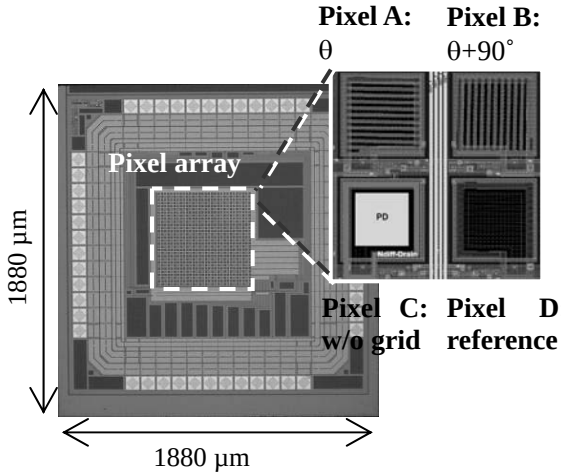

Fig. 5. The new sensor design for polarization measurement.

Table II. Specifications of the new CMOS sensor.

Process	0.35 μm 2poly 4metal Standard CMOS
On-chip Polarizer	Line/Space=0.6 μm/0.6 μm (1.2 μm pitch)
Pixel size	20 μm x 20 μm
Photodiode size	10 μm x 10 μm (25 %)
Array size	30 x 30 (15 x 15 pixel sets)
Partial pixel array	A: 20 x 20 (10 x 10 pixel sets) B-E: 10 x 10 (5 x 5 pixel sets)
Operating Voltage	3.3 V
Chip size	1880 μm x 1880 μm
Readout	Analog Voltage, 4 channel