Extended Abstracts of the 2012 International Conference on Solid State Devices and Materials, Kyoto, 2012, pp382-383

Real-time multifunctional optical analyzer based on polarization-analyzing CMOS image sensor for microchemical systems

Norimitsu Wakama, Nobuya Tachikawa, Kimitada Terao, Mikiko Shibata, Toshihiko Noda, Kiyotaka Sasagawa, Takashi Tokuda, Yasuhiro Nishiyama, Kiyomi Kakiuchi and Jun Ohta

Graduate School of Materials Science, Nara Institute of Science and Technology.
8916-5 Takayama, Ikoma, Nara, 630-0192, Japan
Phone: +81-743-72-6051 E-mail: ohta@ms.naist.jp

1. Introduction

We have proposed to implement a multifunctional CMOS sensor onto michirochemical systems, and developed a polarization-analyzing CMOS image sensor to realize chiral measurements in microchemical systems [1], [2]. In this approach, on-pixel polarizers are configured using metal wiring layers in a standard CMOS technology. Polarizers with different angles are implemented on pixels and we can measure polarization angle of incident light. In this paper, we designed a polarization-analyzing CMOS image sensor with 9 polarizer sets. We also developed an in-line optical analyzer which is capable of measuring optical rotation and absorbance simultaneously.

2. Design of polarization-analyzing CMOS image sensor

We have designed a polarization analyzing CMOS image sensor using a 0.35 μm standard CMOS technology. Fig. 1 shows a layout of the sensor. Table I shows specifications. Pixel circuitry is 3-transistor active pixel sensor (APS). Fig. 2 shows the cross sectional structure of the on-chip polarizer. On-chip polarizer was designed with the bottom metal wiring layer above a photodiode of the pixel. Line / space widths of the on-chip polarizers are 600 nm / 600 nm. The sensor is equipped with 9 sets of polarizer arrays that covers all the angles from 0 deg. to 179 deg. The step for the polarizer angle was 1 deg. We took intraframe averaging using 9 estimated angles obtained with each partial pixel array and inter-frame averaging of the pixel value. The typical noize level for the polarization analysing function was as large as σ=0.0061 degrees [1].

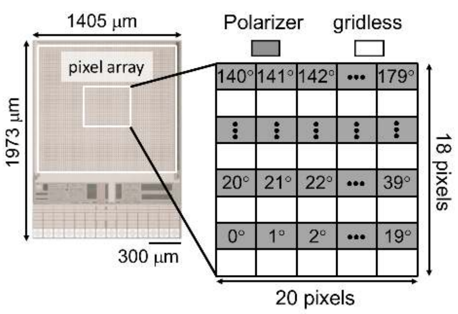

Fig. 1 Micrograph of the polarization-analyzing CMOS image sensor using 0.35 μm standard CMOS process

Table I Specifications of the Polarization-Analyzing CMOS Image Sensor

Technology	0.35 μm 2poly 4metal standard CMOS
Number of pixels	64 × 64
Pixel size	20 μm × 20 μm
PD size	10 μm × 10 μm
Photodiode	nwell-psub
Pixel readout	3-Tr Active Pixel Sensor
Chip size	1405 μm x 1973 μm
Line / space of grid polarizer	600 nm / 600 nm
Polarizer angle	0 ~ 179 deg. (1 deg. step)

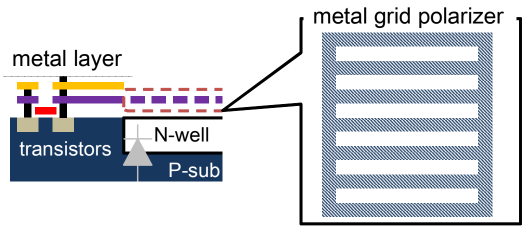

Fig. 2 Cross sectional structure of the polarization analyzing pixel

3. Real-time chiral analysis system

Fig. 3 shows configuration of the chiral analysis system. A light emitting diode (LED) (peak: 650 nm, filtered to 633 nm) was used as light source for optical rotation measurement. Linearly-polarized and collimated light beam was formed. We have also implemented a function of single-wavelength optical absorption measurement. An ultraviolet LED with peak wavelength of 405 nm was used as a light source for absorption measurement. Collimator lenses, band-pass filters, and a polarization beam splitter were used to form coaxial light beams for polarization-analyzing and absorption measurement function. A Z-shaped flow-cell was placed between the beam splitter and the image sensor. Evaluation of the proposed system was performed with a model photochemical reaction of diastereoselective [2+2] photocycloadditions [3]. First of all, the flow-cell was filled with toluene (blank solution). After the sensor output got stable, we injected substrate solution. After the transition of the estimated polarization angle was stabilized, we turned on a mercury lamp to start the model photoreaction. Fig. 4 shows the results of the optical rotation and the single-wavelength absorbance measurement function. Clear

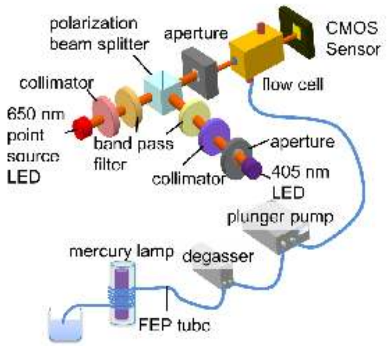

Fig. 3 Measurement system for absorbance and optical rotation

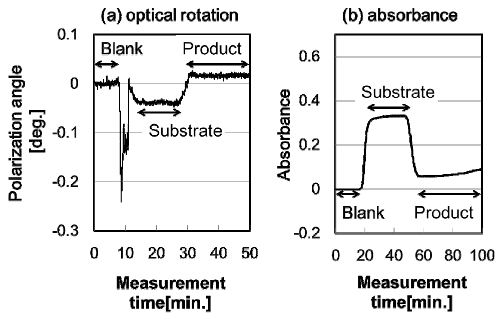

Fig. 4 Measurement results of (a) optical rotation and (b) absorbance

transitions of the measured optical characteristics were observed in the traces. We have also confirmed the changes observed in the traces are consistent with reported values. Typical transition time was approximately five minutes that is consistent with the time estimated with the ratio of cell volume and flow rate.

4. Simultaneously real-time chiral analysis

Optical rotation and absorbance were simultaneously measured by altering two LEDs at an interval of 90 seconds. We used product solution prepared in advance and replaced the plunger pump in Fig. 3 with a syringe pump. We sequentially injected the blank, the substrate, and the product with the syringe pump. Fig. 5 shows the results of the optical rotation and absorbance measurements. We successfully obtained both results in the same time course.

5. Design of the polarization-analyzing CMOS image sensor with 65nm standard CMOS technology

The performance of the on-chip polarizer depends on the pitch of the wire grid structure. An advanced CMOS technology is advantageous to configure on-chip polarizers with smaller grid pitch. We have demonstrated an extinction ratio of more than 40 with single-pixel test device fabricated with 65 nm standard CMOS process [4]. We have designed a polarization analyzing CMOS image sensor with 65 nm standard CMOS technology. Fig. 6 shows layout of the image sensor. The sensor is equipped with 512 sets of 0 deg. and 90 deg. polarizers.

6. Conclusions

A novel in-line multifunctional optical analyzer was

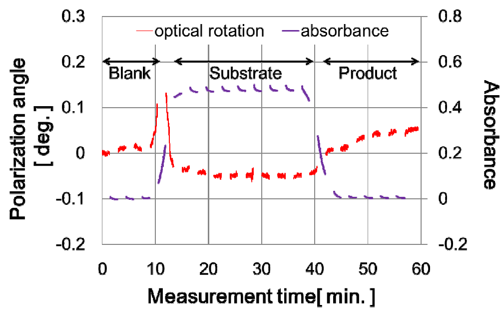

Fig. 5 Simultaneously measurement results of absorbance and optical rotation.

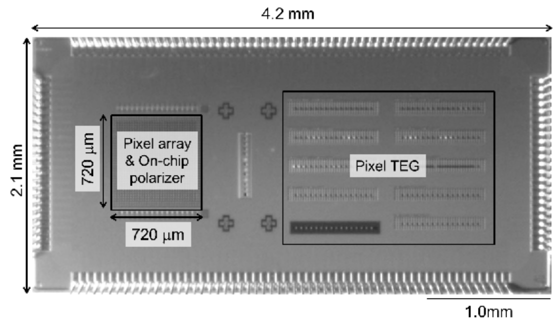

Fig. 6 Micrograph of the polarization-analyzing CMOS image sensor using 65 nm standard CMOS process

proposed and demonstrated. The device was capable of measuring optical rotation and single-wavelength absorbance. A polarization analyzing CMOS image sensor, the core device of the in-line optical analyzer was designed with 0.35 μm standard CMOS technology. We characterized the optical analyzer and successfully demonstrated the dual functionality. In order to further improve the performance, we also developed a polarization-analyzing CMOS image sensor with 65 nm standard CMOS technology.

Acknowledgements

The research in Section 5 was supported by STARC as part of the Japanese Ministry of Economy, Trade and Industry sponsored "Silicon Implementation Support Program for Next Generation Semiconductor Circuit Architectures". This work was also supported by Grant-in-Aid for Scientific Research #24310101 and Grant-in-Aid for Scientific Research on Innovative Areas #24106729 from the Ministry of Education, Science, Sports and Culture, Japan, and by the VLSI Design and Education Center (VDEC), University of Tokyo, in collaboration with Cadence Design Systems, Inc.

References

[1] T. Tokuda, S. Sato, H. Yamada, K. Sasagawa, and J. Ohta: Electron. Lett., 45 (2009) 228.
[2] T. Tokuda, Y. Takeuchi, Y. Sagawa, T. Noda, K. Sasagawa, k. Nishida, T. Fujikado, and J. Ohta: IEEE Trans. Biomed. Circuits and Systems, 4 (2010) 445.
[3] K. Tsutsumi, Y. Yanagisawa, A. Furutani, T. Morimoto, K. Kakiuchi, T. Wada, T. Mori and Y. Inoue: Chem. Eur. J. 16 (2010) 7448.
[4] S. Shishido, T. Noda, K. Sasagawa, T. Tokuda and J. Ohta: Jpn. J. Appl. Phys. 50 (2011) 04DL01.