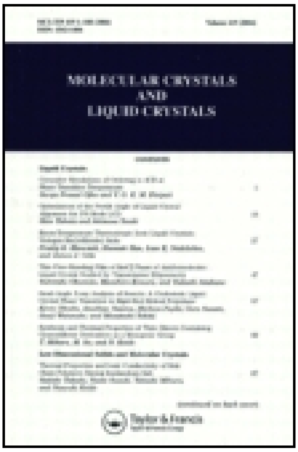


Molecular Crystals and Liquid Crystals
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/gmcl20

"AND" Logic Function of Molecular Photodiode Consisting of GFP/TCNQ Hetero-Film

Jeong-Woo Choi [a b], Yun-Suk Nam [a], Se Yong Oh [a], Won Hong Lee [a] & Masamichi Fujihira [b]

[a] Department of Chemical Engineering, Sogang University, Seoul, 121-742, Korea

[b] Department of Biomolecular Engineering, Tokyo Institute of Technology, Nagatsuta, Yokohama, Japan

Version of record first published: 29 Oct 2010

Mol. Cryst. Liq. Cryst., Vol. 377, pp. 249-252

1058-725X/02 $12.00 + .00
DOI: 10.1080/10587250290089374

"AND" Logic Function of Molecular Photodiode Consisting of GFP/TCNQ Hetero-Film

JEONG-WOO CHOI[a,b], YUN-SUK NAM[a], SE YONG OH[a], WON HONG LEE[a] and MASAMICHI FUJIHIRA[b]

[a]*Department of Chemical Engineering, Sogang University, Seoul 121-742, Korea and*
[b]*Department of Biomolecular Engineering, Tokyo Institute of Technology, Nagatsuta, Yokohama, Japan*

Molecular logic gate device with "AND" logic function was developed. In this research, the "AND" function logic gate was fabricated with double line structured bio-photodiode consisted of GFP/ TCNQ hetero-film. When a light was irradiated to a single (A or B) or double (A and B) line bio-photodiode as input, the steady state photocurrent was generated in part of "A+B" as output. The photocurrent intensity generated in single line input, was lower than that of double line input. The high photocurrent intensity indicates (1,1) in truth tables and low photocurrent indicates (0,1) or (1,0). Finally, (0,0) input corresponds to a dark state without light generation. The "AND" gate function was successfully achieved based on high- and low-photocurrent.

Keywords: Molecular photodiode; Green fluorescent protein (GFP); Transient photocurrent; logic gate; AND logic function

INTRODUCTION

The fields of microelectronics and computation have been advanced at an amazing rate over the past few decades, and at the heart of these advances has been the technology of the complementary metal-oxide semiconductor (CMOS)-based integrated circuit. However, both the fundamental physics of CMOS devices and the increasingly prohibitive costs associated with constructing next-generation fabrication facilities indicate that this technology is rapidly maturing[1]. Nevertheless, the physics of computation is still in its infancy. Many researchers are exploring alternative to CMOS-based computational machinery, including such options as single electron transistor, quantum cellular automata, molecular computation, and chemically assembled electronic nanocomputers.

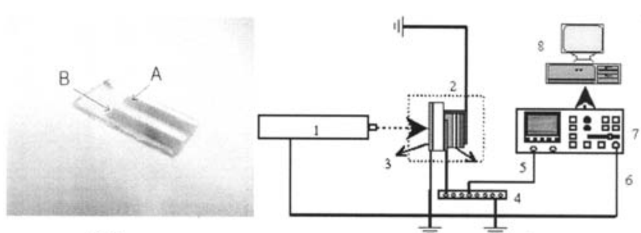
To substitute for the CMOS-based computation, the molecular bio-logic gate based on the molecular bio-photodiode is developed[2]. In this study the molecular bio-logic gate with "AND" logic-function was investigated by bio-photodiode and variable optical measurement.

EXPERIMENTAL DETAILS

Using GFP (sensitizer), and TCNQ (acceptor), the hetero-type LB film was fabricated onto the ITO coated glass. To fabricate the metal/insulator/metal (MIM) structured device, the aluminum was deposited onto the hetero-film surface. For the logic function generation, molecular photodiode was constructed with double line structure. The proposed "AND" logic-gate was shown in Fig.1(a).

Laser light is irradiated to single or double line bio-photodiode, and the generated photocurrent is summated. Thus, the high and low photocurrent intensities in single and double line were easily distinguished from one another by thresholds.

In order to investigate the photocurrent generation and to prove the logic function, steady state photocurrent were measured and analyzed.



(a) (b)

FIGURE 1. (a), "AND" function bio-logic gate, (b), The schematic setup for the photocurrent measurements: 1; N_2 gas laser, 2; sample device, 3; Cu plate, 4; preamp SR240, 5; signal input, 6; trigger input, 7; Oscilloscope HP 54610B

Fig. 1(b) shows a schematic diagram of the experimental system for the photocurrent measurements. The light pulse from the laser system consisting of a N_2 gas laser (6mW, 400μj, VSL-337ND, LSI, USA) was introduced to excite the GFP molecules. Pulse width and frequency were 10ns and 200MHz, respectively. With fast electronics using a 300 MHz frequency V/V amplifier (Model SR 240, Stanford research) and a storage oscilloscope of 500MHz frequency (HP 54610B, Hewlett-Packard, USA), the interlayer photocarrier movement was detected from a 50 Ω strip line geometry in order to acquire signals with high time resolution.

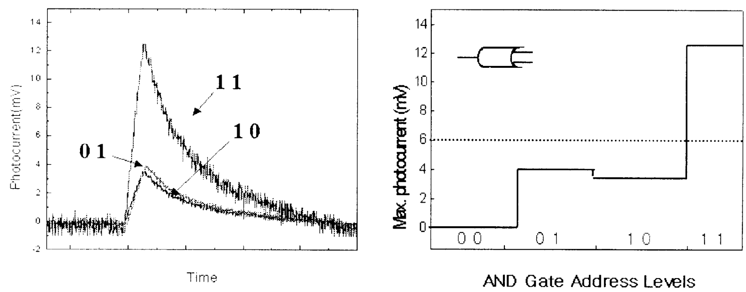
RESULTS AND DISCUSSION

In this logic gate, the low photocurrent intensity in single input indicates logically (0,1) or (1,0) in truth tables. On other hands, the high photocurrent generated in double input indicates (1,1) in truth tables. Laser light is irradiated to the molecular bio-logic gate in part A and/or B. If light is irradiated onto A or B (1,0 or 0,1), photocurrent intensity and decay of the device are nearly the same. However, light is irradiated onto A and B (1,1), photocurrent intensity is twice as much as A (1,0) or B (0,1). (0,0) input corresponds to a dark state without light generation, and the photocurrent caused by (0,0) input was not observed.

A	B	Logic factor	Truth level
0	0	0	F
1	0	0	F
0	1	0	F
1	1	1	T

TABLE 1. Truth table for "AND" logic function

Thus, the differentiation of photocurrent intensities in the molecular bio-logic gate was achived. If the threshold as average point of photocurrent intensities is used, logic function is clearly distinguished from one another. Fig.2 (a) shows the experimental photocurrents of molecular bio-logic gate. The photocurrent decay of (1,1) is similar with that of (1,0) or (0,1) but the intensity of "1 1" is clearly different from that of "1 0", "0 1". Photocurrent intensities of (1,1), (1,0), and (0, 1) are about 12.7, 3.5, and 3.8mV, respectively. Thus the high photocurrent of (1,1) is differentiated from that of low (1,0) and (0,1) by the threshold at 6mV. Fig.2 (b) shows the photocurrent intensities corresponds to the AND gate address levels. This result indicates that the high photocurrent intensity of double input (A and B) exhibits logically "True" or "1", and the low photocurrent intensity of single input (A or B) and no light input indicates logically "False" or "0".



(a) (b)

FIGURE 2. (a) The experimental photocurrent results, (b) photocurrent intensities corresponds to the AND gate address levels

This logic gate is similar in principle to diode-based wired-logic gate. A second challenge will be to scale down the size of the device and integrate molecular bio-logic gate with molecular-scale wires, such as conducting DNA or carbon nanotube.

Acknowledgements
This work was supported by the National Program for Super Intelligence Chip of the Ministry of Commerce, Industry and Energy as one of the new technology of next generation.

References

[1.] C.P. Collier *et al.*, Science, **285**, 391 (1999).
[2.] J.W. Choi *et al.*, Applied Physics Letter, **79**, 1570 (2001).