Extended Abstracts of the 2018 International Conference on Solid State Devices and Materials, Tokyo, 2018, pp667-668

Optofluidic Device for Measuring Cell Response Against Mechanical Stimulation

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Abstract

A optofluidic device is developed which can trap and stimulate the cell mechanically. The light beam is irradiated and detected using the optical fibers in a noninvasive manner. The euglena cells are trapped and its transmission spectrum in the static condition and the intensity change under the mechanical pulse are measured.

1. Introduction

Recently, the microfluidics is growing as the attractive technology. Its merit includes saving sample quantity, easier or automatic handling of small cell samples. In addition to this merit, the optical measurement technique is tried to be combined taking the advantage of the noninvasiveness against the bio-sample[1]. Previously, we have reported the microfluidic device combined with optical fiber[2] to measure only the static condition. The dynamic response is considered to have the mechanical information, which is meaningful related to the canceration.

In this study, a new device which can measure the dynamic response against the mechanical situation is developed.

2. Cell Sample

The cell sample here is the euglena, which is the unicellular organism which has both animal's and plant's characteristics[3]. The cell size is about 50μm in length, 10μm in width. It is known to have many nutrition. In anaerobic condition, the euglena generates low melting point wax ester, which can be applied to the fuel of the airplane.

3. Principe and Device Design

For measuring the optical signal from the cell, fixing the cell in the light path is necessary. The cell trapping mechanism is included in the device combined with the optical fiber. Figure 1(a) shows the schematic drawing of the device. There are the trenches for inserting two optical fibers (muti-mode and TEC single-mode) from left and right sides. The bias springs at the trench side push the fiber in both lateral and vertical directions aligning the fiber in the designed position[4]. Between two fibers, the gap is prepared for placing the samples to be measured. Beside the fibers, there are the channels for flowing the liquid with euglena cells. The cell trapping principle bases on the difference of the flow conductance of two channels[5]. One channel is the trap channel and the other is the waste channel. The width of the trap gate is 8μm, which is narrower than the width of the euglena cell. The trap channel is shorter in its length being the path connecting between two fibers directly. The waste channel is longer having the rounded route with the larger fluidic resistance compared to the trap one. When the liquid sample is supplied, the flow prefers the trap channel due to the smaller fluidic resistance bringing the euglena cell. After the euglena is trapped, its flow resistance increases and the follow goes to the waste channel.

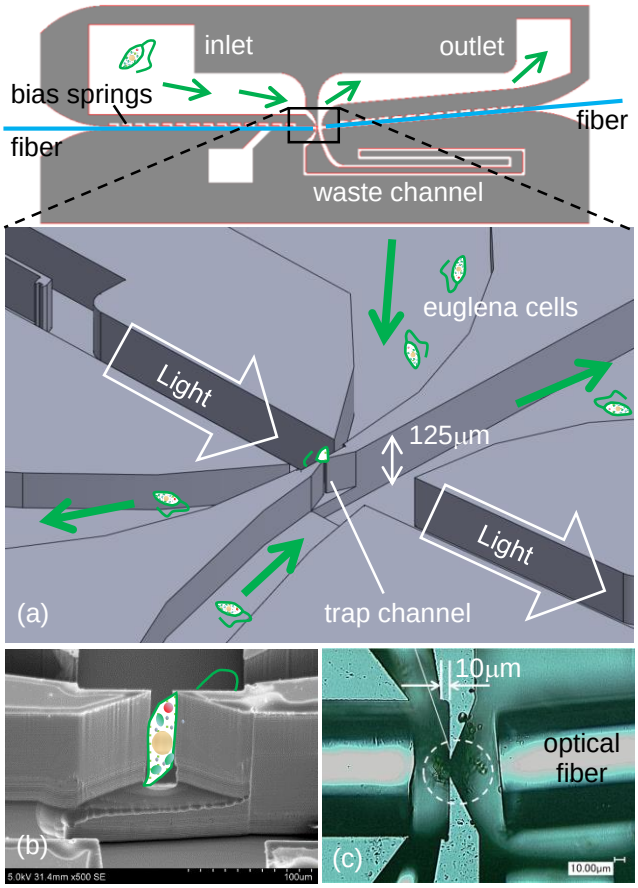

Fig. 1: (a) Schematic drawing for showing liquid flow and trapping of euglena cell. (b) SEM image of the trap gate with the euglena cartoon. (c) Fibers and the trapped euglena cells.

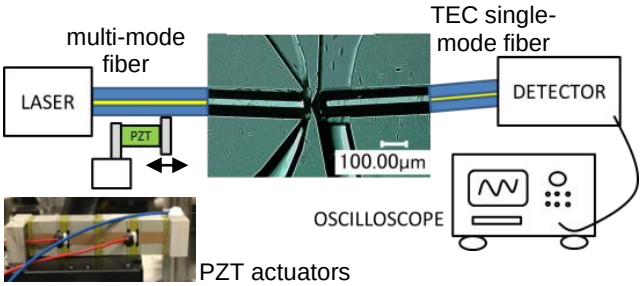

Fig. 2: Setup for the mechanical pulse response measurement for showing actuator setup for driving optical fiber.

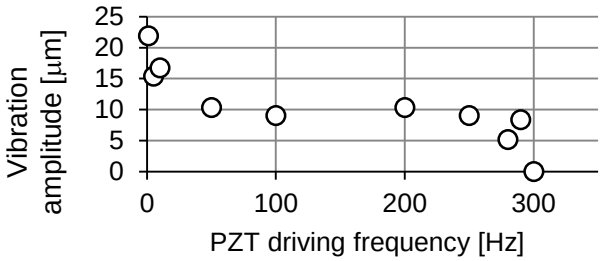

Fig. 3: Displacement of the optical fiber end against the driving frequency of piezo actuator.

Figure 1(b) shows the SEM image of the gate fabricated from Si wafer. The flow channel is shallower than the fiber trenches (depth: 125μm). The bottom of the flow channel is 38μm higher than that of the fiber trench. This is for placing the euglena cell on the light path. The drawing is for showing the size compared to the euglena cell. Figure 1(c) shows the optical micrograph. A few euglena cells are trapped stably.

Figure 2 shows the setup for applying the mechanical force to the trapped cell as the water pressure pulse actuating one optical fiber along the trench using the piezoelectric actuator. The inset photo shows two piezoelectric actuators (AE1010D16DF) glued in series. Since the fiber guide is straight, the linear displacement can transmit. The green laser having the wavelength of 532nm is irradiated to the euglena cells. The PIN photodiode detects the transmission light intensity. Figure 3 shows the displacement of the optical fiber end against the driving frequency. The vibration amplitude is measured using the high-speed camera. The sinusoidal driving voltage is 60V in peak to peak having 30V offset. The cut-off frequency is about 300Hz.

4. Optical Transmission Spectroscopy

Figure 4 shows the optical transmission spectra obtained from the device. The transmission light can be observed although two fibers have the tilt angle of 5°, which is for increasing S/N ratio of the scattered light described later. One curve is when the sample is water. Another is observed with the euglena trapped. The absorption peak at around 680 nm in wavelength corresponds to the chlorophyll a.

5. Mechanical Pulse Response Measurement

Under the mechanical pulse, the time-dependent optical signal is measured caused by the scattering at the cell. Figure 5(a) shows the applied pulse driving at 0s having the width about 1ms. The fiber end does not contact with the cell but the small movement is measured. Figure 5(b) shows the scattered light intensity after the mechanical impulse. The signal returns to the original value. The response period is about 17ms. Inside this curve, some characteristic waves are observed. They are considered to show the mechanical hardness of the cell and the inside organs. When the sample is water for comparison, the light intensity does not change. 40 samples are measured obtaining the response period of 20.1ms in average, and its standard deviation of 8.43ms.

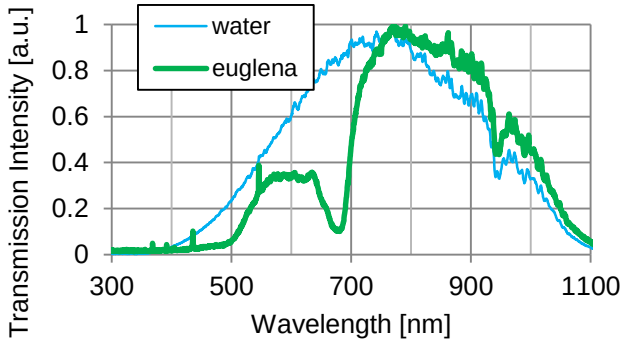

Fig. 4: Transmission spectra obtained from water with euglena's and pure water.

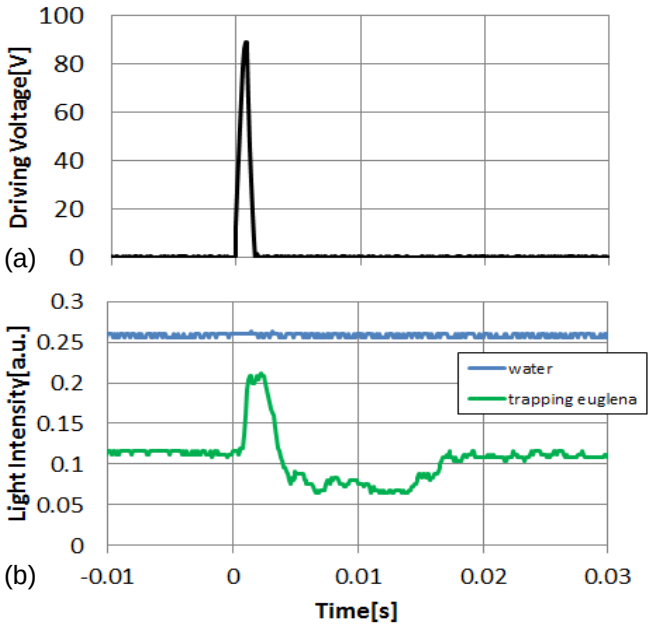

Fig. 5: Typical pulse waveform for driving the piezo actuator and the response of the transmitted light intensity scattered at the trapped euglena cell.

6. Conclusions

A new optofluidic device is realized which can trap the euglena cell for measuring its optical signal and time response applying the mechanical stimulation.

Acknowledgements

This study is supported by MEXT Program for Forming Strategic Research Infrastructure (S1311034) and the Nano-technology Platform Project, Japan.

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