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Si Micro-Optical-Bench Combining with Fiber and Flow Channel for Absorption Spectroscopy of Cells in Suspension

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Abstract

A new Si micro-optical-bench is fabricated for obtaining the absorption spectroscopy of the cells in suspension. Since the cells tend to sink to the micro-channel bottom, its position is set to the height of the core of the optical fiber. The observed absorption can be assigned to the chlorophyll of the chlorella.

1. Introduction

The microfluidic devices in μ-TAS (total analysis system) handle a small amount of liquid in a controlled and material-saving manner. Their analysis is mainly based on the chemical method. As for the living bio-samples such as cells in water, applying the chemical reaction often means stopping the bio-activity. The measurement methods keeping the bio-activity are expected. The optical spectroscopy is known as the non-invasive method applied in the natural condition (for an application example, sensing degree of maturity of fruits). The transmission optical spectroscopy is appropriate minimizing the complicated effect of the reflection at the interfaces.

The optical fiber consists of core and clad. The clad protects the guided light in the core from the disturbance. So, once the mechanical setting of the fiber is obtained, the functional combination can be obtained. The super continuum light[1] is one attractive candidate for the future light source. So far, we have reported a device focusing on the bias spring for aligning the optical fiber[2, 3]. In this study, a new Si micro-optical-bench is fabricated designing for the bio-sample having the specific size and density to measure the absorption spectrum of the cell in liquid.

2. Cell Sample and its Positioning

The sample used is the chlorella cells having the spherical shape with the average diameter of 6.3 μm. This is a plant cell with chlorophyll. The cell photosynthesizes the starch. The chlorophyll is known to have the absorption peak wavelengths at 400-500 and 650-700 nm. The density of the chlorella cell is a little larger than that of the water, and the cell gradually sinks to the bottom of the micro-channel. Since the cell sample is necessary to be in the light path for the spectroscopy, the fiber core position is necessary to be near to the floor of the micro-channel. Figure 1(a) shows the vertical design. The clad thickness of the fiber makes the core position of the optical beam higher than the trench bottom. The micro-channel bottom is designed to be higher than the trench bottom for the optical fiber guide.

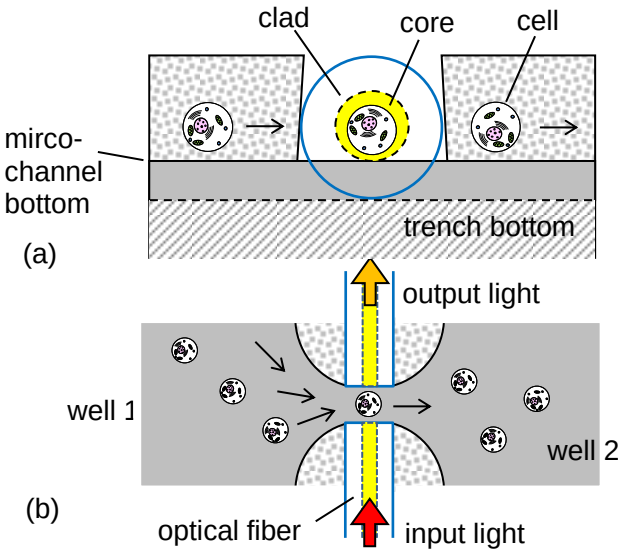

Fig. 1 (a) The vertical design for passing the light beam to the cell in suspension. (b) The lateral design combining the micro-channel and the optical fibers for the absorption spectroscopy of the cells.

3. Design

Figure 1(b) shows the lateral design. Two optical fibers are placed along the guide facing their end surfaces. The micro-flow passes in the gap between two optical fibers. For obtaining the transmission light through the gap, the alignment accuracy (position and angle) of two fibers should be high. This is realized by the trench with the bias springs. A multi-mode optical fiber is used. The diameter of the optical fiber and core are 125 μm and 50 μm, respectively. So, the clad thickness is 37.5 μm. Bottom of the micro-channel is designed to be about 37 μm high.

4. Fabrication

Figure 2 shows the fabrication sequence. Si micro optical bench is fabricated from SOI substrate (thickness of device layer: 125 μm, buried oxide layer: 1 μm) making the structure with 2 different depths. (1) The photoresist is patterned and UV-cured. (2) The second photoresist is patterned. (3) Using the top photoresist layer as a mask, Si is etched. Next, O_2 ashing is performed to remove the top deposition film and the top photoresist film is flush exposed and developed to be removed. (4) UV-cured photoresist mask appears. (5) The second Si etching is conducted. The

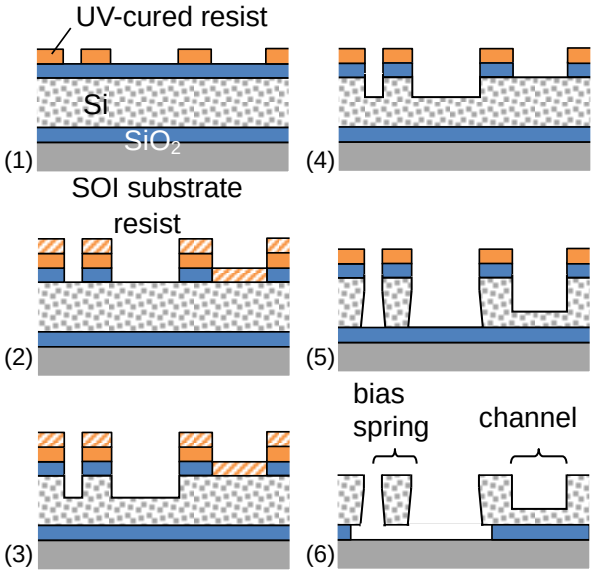

Fig. 2 Fabrication sequence for realizing the structure with two different depths.

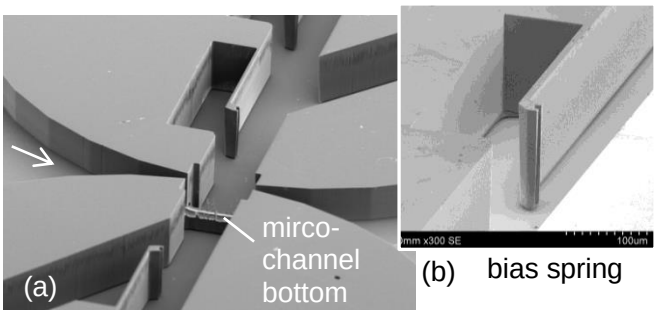

Fig. 3 (a) Fabrictged Si micro-optical-bench for setting two optical fibers and the micro-channel between them. (b) Magnified image of the bias spring.

etching time controls the bottom height of the micro-channel. (6) The buried oxide layer is etched by the concentrated HF to release the bias springs for holding the optical fiber.

5. Results and Discussion

Figure 3(a) shows SEM image of Si micro-optical-bench at around the fiber gap and the micro-channel. The vertical trench having a constant width is for setting the optical fiber. The lateral trench narrowing at the center is for passing the liquid. This bottom is higher than that of the trench for the optical fiber. Figure 4 shows the depth profile of the device measured by the white light interferometer. The depth difference between two bottoms is 37 μm, well-agreed with the design value. This bottom structure is mechanically robust allowing the fiber contact. Figure 3(b) shows the bias spring released from SOI handle layer. The trench and the bias springs have reversed-taper at the sidewall (about 1^{O}). The bias springs push the fiber to the opposite trench sidewall and bottom. Each fiber is aligned along the micro-channel being pushed by 10 bias springs.

The suspension containing chlorella cells is poured in the micro-well. One well has the cotton assisting the vaporizing

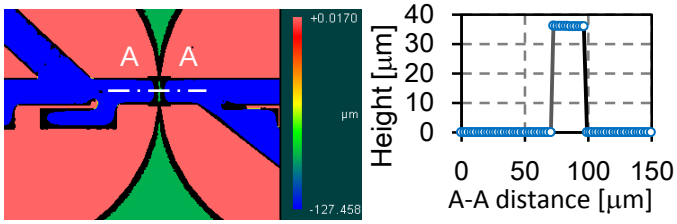

Fig. 4 Height profile of the device. The black region means the area with little light information.

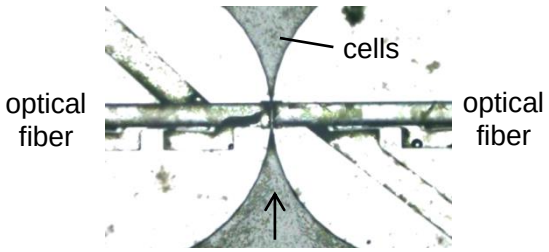

Fig. 5 Optical micrograph confirming the suspension flow with chlorella cells through the gap between fibers.

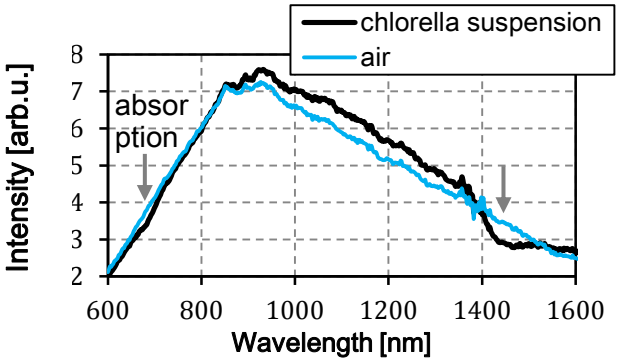

Fig. 6 Measured transmission spectrum of the chlorella suspension and the air.

of water from the well. This causes the liquid flow gathering water from the opposite well as shown in Fig. 1(b). Figure 5 shows an optical image. Small dots correspond to the chlorella cells and observed to flow the gap between fibers.

Figure 6 shows the transmission spectrum using the optical spectrum analyzer (Anritsu, MS9780A). The light source is the usual halogen lamp (Anritsu, MG922A). The black line is obtained from the suspension with chlorella cells. The light blue line is from the air gap. The spectra are similar each other except the absorptions at 680 nm and 1440 nm. The former will relate to chlorophyll. The latter will relate to water molecule.

Acknowledgements

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