Thesis Summary

Fabrication of paper-based microfluidic devices using a laser beam scanning technique

（レーザービーム走査法を用いたペーパーマイクロ流体デバイスの作製）

Dang Huy Hiep

Chapter 1 shows the Introduction. The paper-based microfluidic analytical device (μ-PAD) has been attracted great interest since it possesses beneficial characteristics such as easy-to-use, biocompatible, inexpensive, and so on. Therefore, it is considered that the μ-PADs are especially important to use in developing countries where the expensive equipments are rare to use because of the finance issues. Now a large variety of fabrication techniques are available. Among them, the method using a laser beam has an advantage that microchannels can be directly created on paper without using a photomask. There are two types of strategies to create microchannels on paper using a laser beam. One is to fabricate hydrophobic barriers on hydrophilic paper by photo-polymerization. The other is to fabricate hydrophilic channels on hydrophobic paper by laser-irradiation. Herein, we propose a new approach to fabricate hydrophilic channels on the hydrophobic paper using a laser beam scanning technique.

Chapter 2 shows the experimental section. CPI-410S was supplied by San-Apro Ltd. and used without further purification. The structure of CPI-410S was shown in the Supporting Information, Figure S1. OTS and Acid Red 1 were purchased from Sigma Aldrich-Merck Co. Dimethyl sulfoxide, chloroform, *n*-hexane, and ethanol were purchased from Wako Pure Chemicals Co. Ltd. and used without further purification. Water was purified by reverse osmosis and deionization prior to use (Merck Millipore, Milli-Q Integral 3). Cellulose chromatography papers (Advantec Co., Ltd.) were immersed in 0.1% (v/v) OTS *n*-hexane solution for 5 min at room temperature. The papers removed from the OTS solution were rinsed with *n*-hexane and ethanol and dried in air. Subsequently, the OTS-treated papers were immersed in chloroform and 5 % (w/w) CPI-410S DMSO solution for 1 and 2 min, respectively. A diode laser (405 nm, 300 mW, Changchun New Industries Optoelectronics Technology Co., Ltd., MDL-III-405-300) and a xenon lamp (150 W, Hamamatsu photonics K.K., L2274) were used as an excitation light source for CPI-410S. A Galvo mirror system (Thorlabs, Inc., GVS002) was used to scan the laser beam.

Chapter 3 shows the results and discussion:

The contact angle of water droplets on the OTS-treated paper under photoirradiation

After hydrophobilizing by octadecyltrichlorsilan, the hydrophilic patterns were created by the hydrolysis of the silyl ether bond between cellulose and OTS, which was triggered by the photoinduced acid generation reaction of CPI-410S. In order to confirm that the CPI-410S can remove OTS in the paper under photoirradiation by xenon lamp, When the light irradiation time was 50 min, the contact angle of the water droplet became 0°. This result clearly shows that the hydrophobic paper has turned into a completely hydrophilic one.

Hydrophilic-hydrophobic contrast in the photo-irradiated OTS-treated paper

To fabricate hydrophilic channels on OTS-treated papers, it is necessary that only the photo-irradiated area becomes hydrophilic. Prior to the laser beam scanning experiment, the hydrophilic-hydrophobic contrast at the boundary between the photo-irradiated and the photo-masked area was examined. To investigate the hydrophilic or hydrophobic properties, aqueous droplets containing Acid Red 1 were dropped on the upper and lower parts of the paper, respectively it was clearly visible that a hydrophilic-hydrophobic boundary was formed between the photo-irradiated and the photo-masked area. This result clearly indicates that the change from hydrophobic to hydrophilic nature of the OTS-treated paper was caused by the photochemical reaction with CPI-410S.

Hydrophilic patterns fabricated on the OTS-treated paper using the laser beam scanning technique: By using a laser beam as a light source for the photochemical reaction and scanning the beam to draw an arbitrary spatial pattern on the paper, it should be possible to fabricate hydrophilic channels directly on the OTS-treated paper without using a photomask. To demonstrate this idea, using a computer-controlled Galvo mirror system, a 405-nm laser beam was scanned in a star pattern on the OTS-treated paper containing CPI-410S. The width of the pale-yellow colored channel observed under an optical microscope was about 50 μm. When a water droplet containing Acid Red 1 was dropped on one vertex of the star, the aqueous solution spread along the channels via capillary forces

Quantitative analysis of nitrite: Nitrite ion in the samples were detected successfully by a created device.

Chapter 4 shows the conclusion