Fabrication of lab-on-a-chip by direct dry etching of PTFE using SR

The rapid detection and characterization of chemical analytes such as biological markers in tissue and fluid samples are a major challenge in medicine and environmental analysis. Recently, for the development of integrated and miniaturized microfluidic devices to achieve analysis, considerable attention has been devoted to micro-total analysis systems (μTAS). For example, a novel μTAS has been required to achieve the sequence of analysis operations for amino acids in extraterrestrial samples, which include extraction, filtration, hydrolysis, and evaporative drying. Precise analysis of the amino acids contained in extraterrestrial samples is very important in the study of the origin of life. We have recently had opportunities to analyze fresh extraterrestrial samples obtained by the collection of cosmic dust and samples returned from asteroids [1]. However, the amounts of the samples that can be used for analysis are limited because of their small amount. Therefore, amino acid analyses of the samples using a microfluidic chip are required.

Polytetrafluoroethylene (PTFE) has high chemical resistance and heat resistance, enabling analytical operation under severe conditions. Although PTFE has high chemical stability, its microfabrication is difficult because its small modulus of elasticity makes it unsuitable for normal mechanical processing. So far, microfluidic devices made of PTFE have not been reported. It is known that synchrotron radiation (SR) induces the scission of polymer chains of PTFE [2,3]. Figure 1 shows the mechanism of the direct dry etching of PTFE using SR. We have fabricated PTFE microstructures by direct dry etching using SR at BL2 in NewSUBARU [4,5]. Figure 2 shows scanning electron microscope images of microfabricated PTFE plates using the SR dry etching process. As shown in Fig. 2, SR dry etching enables the microfabrication of PTFE. The combination of a PTFE microstructure fabricated using SR dry etching and compression bonding enables us to realize a PTFE microfluidic chemical analyzer.

Recently, we have developed a novel microfluidic device that had multiple microchannels and incorporated a filter structure for filtration. We also designed and manufactured novel amino acid analysis devices [5]. Figure 3 shows a schematic diagram of a fabricated amino acid analysis device. This device consists of two chips, and the function of a valve is performed by sliding the upper chip. The microchannels are incorporated into the lower chip. The lower chip has four reservoirs for reagents such as a derivatization reagent, and each reservoir can hold 10 μl. In addition, we formed two reaction reservoirs for extraction and derivatization in the lower chip. The extraction reservoir has a microfilter for the filtration of proteins contained in the sample on the downstream side of the reservoir. We set the filter dimensions to 50×50 μm^2 because the extraterrestrial sample is assumed to be 10–200 μm in diameter. The derivatization reservoir is used for the hydrolysis of proteins to amino acids and for fluorescent derivatization. The heating operations in the derivatization reservoir include closed and open heating operations. We

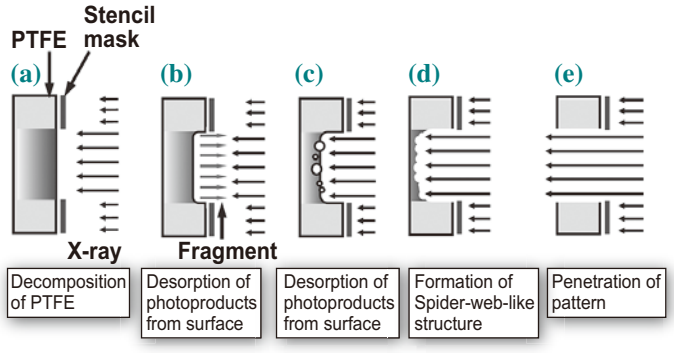

Fig. 1. Mechanism of direct dry etching of PTFE using SR.

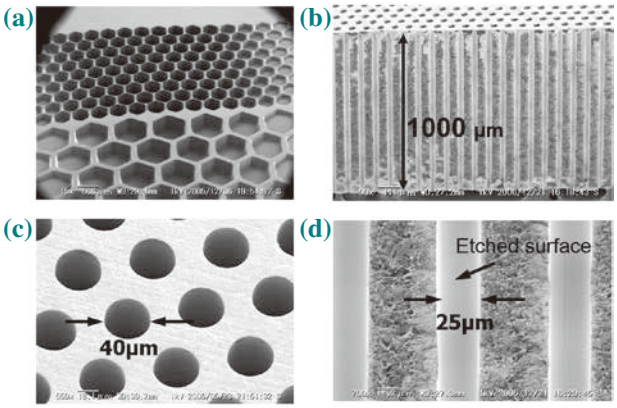

Fig. 2. SEM images of **(a)** honeycomb patterns, **(b)** cross section of through holes, **(c)** top view of through holes and **(d)** magnified cross section of through holes.

demonstrated both heating modes in a single reservoir by opening and closing the upper part of the reservoir. In addition, a filter structure is incorporated in the derivatization reservoir to prevent liquid leakage.

There have been no previous reports of the application of such a complex microstructure made of PTFE as a device for chemical analysis. This study is very important for the progress of science, technology and space development because our device has the potential to perform chemical analysis at the laboratory level at locations difficult to visit.

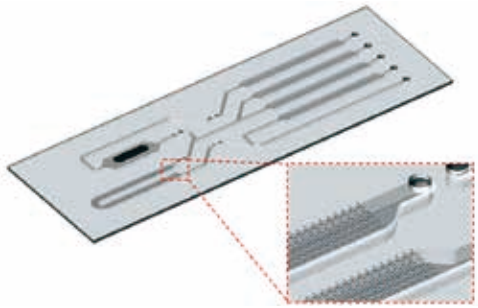

Fig. 3. Schematic diagram of amino acid analysis chip

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References

[1] D.E. Brownlee *et al.*: J. Geophys. Res. **108** (2003) 8111.
[2] Y. Zhang *et al.*: Appl. Phys. Lett. **67** (1995) 872.
[3] Y. Utsumi *et al.*: Jpn. J. Appl. Phys. **44** (2005) 5500.
[4] Y. Ukita *et al.*: Microsyst. Technol. **14** (2008) 1567.
[5] H. Kido, I. Okada, H. Mita, A. Yamaguchi and Y. Utsumi: 10th International Workshop on High Aspect Ratio Micro and Nano System Technology (HARMNST), Berlin, 2013.