International Training Program

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This report was written about International Training Program (ITP) launched by Japan Society for the promotion of Science (JSPS). It aims to strengthen overseas research and education opportunities for young researchers. The reporter participated in this program, and reported about the partner school and the group, difference between research systems in Japan and Netherlands that is a partner country, and research activities of this program in this document.

The purpose of this program held as "Program for incubating young researches on Plasma Nanotechnology Material & Device Processing" by Plasma Nanotechnology Research Center (Graduate School of Engineering) is learning new applications of plasma technology. Author studied at MESA+ institute for nanotechnology for 2 months in University of Twente. MESA+ is one of the largest nanotechnology research institutes in the world, and it has the central role in NanoNed that is national project for nanotechnology of Netherlands. The institute employs 500 people of which 275 are PhD's or postdocs. The structure within MESA+ supports and facilitates the researchers and stimulates cooperation actively. MESA+ combines the disciplines of physics, electrical engineering, chemistry and mathematics. Internationally appealing research is achieved through this multidisciplinary approach. It is strengthening its international academic and industrial network by fruitful cooperation programs. Reporter measures in study of micro- and nano-fluidic devices fabricated with MEMS technology which aims application to a medical care and a medical diagnosis. 1st International Conference on Miniaturized Systems for Chemistry and Life Sciences (μTAS), that is the biggest and most prestigious conference in this field, was convened at University of Twente. University of Twente have lead the world since the concept of μTAS had be proposed.

The author worked in the laboratory of Prof. van den Berg (BIOS - The lab on chip group in University of Twente.) for 60 days, from January 10th 2010 to March 16th 2010. The BIOS-chair ("Miniaturized systems for biocmedical and environmental applications") aims at the research and development of Lab-on-a-Chip (LOC) systems. They have main four missions; (i) futher the knowledge and understanding of nanofluidics, (ii) bridge the gap between users from physical, chemical, biomedical and life-sciences fields, (iii) the development of new micro- and nanotechnologies (iv) demonstrate the potential of LOC applications. BIOS group is one of the greatest laboratory in study of micro- and nano-fluidic devices. Most of members belonging to the group are research associate. The group consists of 44 members, 7 scientific staffs, 2 visiting professors, 5 technical staffs. There are only 5 master students among 44 members in the group. For development of inovative LOC devices, applications, fabrication method and detection systems, principles and application to other fields have been studied under scientific staffs. They put all of the results together, and then go to the next step. This system is more "a research laboratory" than "a research institute".

Alternatively, technical staffs make a huge contribution to research activity. They manage all chemicals; regulate all laboratory instruments; and give advice to researchers about experiments, measurements and experimental procedure. They often make instruments and appurtenance at a workshop on the second floor of their buildings. This is great benefit in the area of developing innovative techniques and devices. There is no outer frame, holder and other equipments for new devices. Researchers need to designed them and order, otherwise make them by hand for themselves.

My responsibility in this program was development of a microvalve. The LOC device is like a miniaturized plant. All experimental procedure will be integrated in the device that size is about 20 millimeters square. This integrated device requires microvalves to control fluid.

Various strategy for development of microvalve are reported. PDMS or teflon is used as valve in those works, however, PDMS membrane made by spin-corting is difficult to get high reproducible and high homogeneously thickness, teflon membrane require high pressure for high modulous elasticity of teflon and cumbersome bonding for its chemical stability. In this work, we present a highly-reproducible microvalve fabricating method. This method is based on UV-curable material (NOA 81). This valve is composed of two NOA sheets, one is a fluidic layer and the other is a pneumatic layer. These channels have two different height structure fabricated with three-dimensional PDMS mold. The fuidic layer bond to underside of pneumatic layer and thin film made of NOA is formed between two layers. When vaccum is applied to the pneumatic channel, the NOA membrane is pulled into the pneumatic channel and fluid can flow into the fluidic channel. In a contrasting situation, when pressure is applied to the pneumatic channel, the NOA membrane bend and stop up the fluidic channel.(Figure 1) NOA 81 has advantages over PDMS and teflon membrane, good flexibility, excellent optical quality and solventresistance. (i) NOA 81 has an elastic modullus 3 orders of magnitude higher than PDMS, and 2 orders of magnitude lower than teflon. This avoids sagging effects, even for very low aspect ratio shallow channels, however, doesn't requiered high pressure to bend membrane. (ii) NOA 81 enable the replication of submicron features. Thickness of NOA 81 membrane is controlled by two laayed PDMS molds. (iii) NOA 81 is a product that is developped to bond optical tools. There is no problem in optical measuring. These properties are suitable for fabricating membrane for microvalve.

The first week

Firstly, all necessary procedures were taken. Following this, members of BIOS group and regulations were introduced. Finally, purpose and strategy of this study were discussed.

The second week

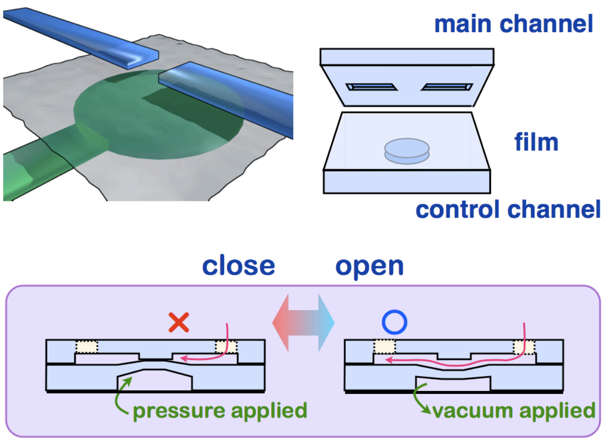

Figure 1 Concept of a microvalve
This valve is composed of two NOA sheets, one is a fluidic layer and the other is a pneumatic layer. These channels have two different height structure fabricated with three-dimensional PDMS mold. The fuidic layer bond to underside of pneumatic layer and thin film made of NOA is formed betweenn two layers. When vaccum is applied to the pneumatic channel, the NOA membrane is pulled into the pneumatic channel and fluid can flow into the fluidic channel. In a contrasting situation, when pressure is applied to the pneumatic channel, the NOA membrane bend and stop up the fluidic channel

Fundamental procedure was learned and repeatedly conducted to acquire it.

The third week

I had discussions with alumnus. He have developed a microvalve at a company. I chose NOA 81 which is light curing reagent to fabricate microvalve and designed dimension of a microvalve.

The fourth week

Designing microvalve was continued. Fabrication of thin film for trilaminar structure microvalve was tried with three different chemicals, fluorocarbon and two light curing polymers. As a result, 6 μm fluorocarbon film, 30 μm light curing polymer films were obtained.

The fifth week ~ the sixth week

SU-8 based masters were fabricated using photolithography techniques on a silicon wafer. A SU-8 precursor, a negative photoresist, was firstly spin-coated on the silicon substrates to give a 45 µm resist layer. This spin coated photoresist was patterned by photolithography technique. After first photolithography, the patterned SU-8 photoresist was spin-coated by the second layer of SU-8 precursor to obtain a 45-µm-thick second resist layer. Finally 3-D structures of SU-8 was developed in RER600. Following this, PDMS pre-polymer was pored and cured on SU-8 based mold. PDMS based mold was peeled off from SU-8 based mold after curing. This process called "soft lithography" is conventional method in developing LOC devices. It is easy to make chips which has high dimensional repeatability and to change channel design such as dimension and shape. In this work, two step photolithography method was used to get 3-D structures.

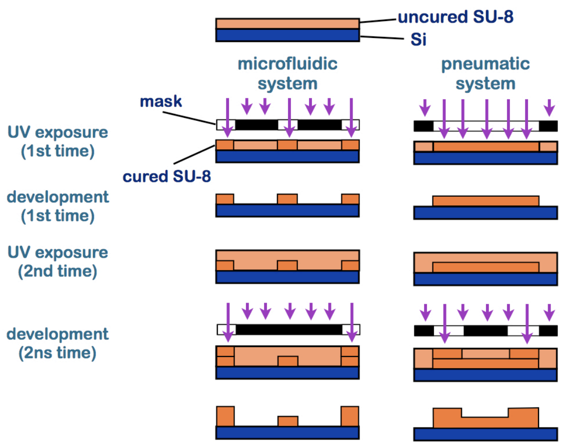

Figure 2 Fabrication of SU-8 based mold
SU-8 based masters were fabricated using photolithography techniques on a silicon wafer. A SU-8 precursor, a negative photoresist, is firstly spin-coated on the silicon substrates to give a 45 µm resist layer. This spin-coated photoresist is patterned by photolithography technique. After first photolithography, the patterned SU-8 photoresist is spin-coated by the second layer of SU-8 precursor to obtain a 45-µm-thick second resist layer. Finally 3-D structures of SU-8 is developed in RER600.

The seventh week

This SU-8-based master is subsequently used for the realization of a PDMS mold. A two-component kit was used for PDMS fabrication; it includes a pre-polymer of PDMS as well as curing agent which were mixed in a 10:1 weight ratio. The resulting mixture was thoroughly degassed in vacuum, subsequently poured into the silicon-SU8 master, anew degassed in vacuum and cured for 12 h at 60°C. After cooling back to room temperature, the PDMS mold was peeled-off from the master. For fabrication of a microvalve made of NOA 81, the PDMS mold of microfluidic system was put on the flat NOA 81 sheet, NOA 81 was then applied from the side of the PDMS mold and spread out slowly between the mold and the NOA 81 plannar chip fabricated between flat PDMS stamps by capillary action prior to curing step for 2 min. After formed NOA 81 microfluidic channels, acces holes were made on reserver. The pneuamtic system was also fabricated by similar procedure as microfludic system but the mold was firstly pressed against another flat PDMS slab before applying the glue from the side of two PDMS molds. It was subsequently cured by UV irradiation for 2 min before peeling the flat PDMS slab

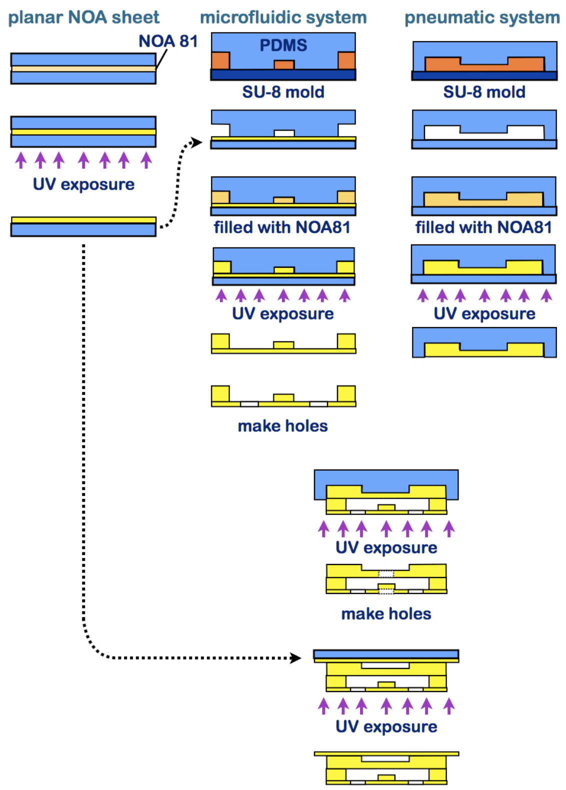

Figure 3 Fabrication of NOA 81 chip

A two-component kit was used for PDMS fabrication; it includes a pre-polymer of PDMS as well as curing agent which were mixed in a 10:1 weight ratio. PDMS poured into the silicon-SU8 master, After curing, PDMS mold was peeled-off from the master. the PDMS mold of microfluidic system was pressed against the flat NOA 81 sheet. NOA 81 was then applied from the side of the PDMS mold and spread out slowly between the mold and the NOA 81 plannar chip fabricated between flat PDMS stamps by capillary action prior to curing step for 2 min. After formed NOA 81 microfluidic channels, acces holes were made on reserver. The pneuamtic system was also fabricated by similar procedure. Then, the microfludic system was aligned and assembled. Finally, the pneumatic PDMS mold is peeled off from the integrated chip, subsequently bonded to the NOA 81 plannar chip and cured by UV light for 2 min.

off. Then, the microfludic system was aligned and assembled to the pneumatic system prior to curing for 2 min. Finally, the pneumatic PDMS mold was peeled off from the integrated chip, subsequently bonded to the NOA 81 plannar chip and cured by UV light for 2 min.

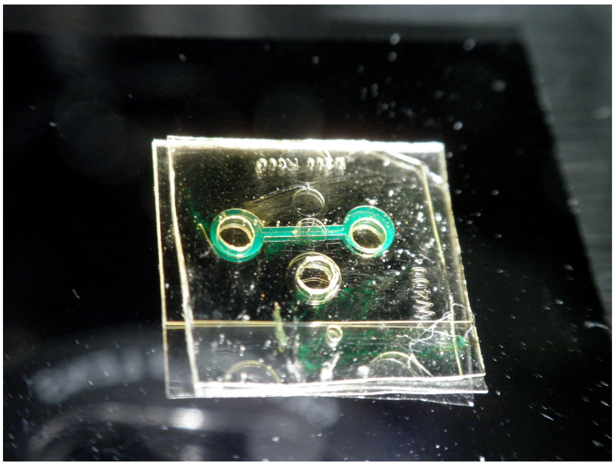

Figure 4 Photograph of fabricated chip
Fluorescein was injected into microfluidics channels. The distance between holes for injection of reagents was 5 mm. The nearest hole is for applying pressure.

The last week

A bonding between channel layer and lid layer did not good when a glass substrate with access hole was used in place of planner sheet made of NOA-81. Because the sticky surface which was inhibited curing reaction at contact surface to PDMS mold was create physical change such as rough surface caused by cure shrinkage, or chemical alteration caused by too long UV light exposing. Leakage test confirmed good bonding between a NOA 81 chip and a planar sheet made of NOA 81.

As for valve characterization, a microfluidic channel filled with fluorescein was observed with fluorescence microscope when a pneumatic channel was applied pressure or vacuum pressure. Fluorescence intensity at the valve member was half value of fluorescent intensity of a microfluidics channel. This result conform to a channel depth. Fluorescence intensity decreased to 0 when applied pressure to a pneumatic channel and the fluorescence intensity recovered after pressure release. This valve performed with 200 μm wide channel or more wide channel, however, the valve with 100 μm wide channel did not work.

Valve performance depends on minimum distance of wall to wall at valve part, and this valve cannot close microfluidic channel completely, for the fluorescent intensity was remained near channel wall. Assuming that deformation of the film at valve part is the same as the model of shear modulous, the film make catenary line. Furthermore valve performance depends of film

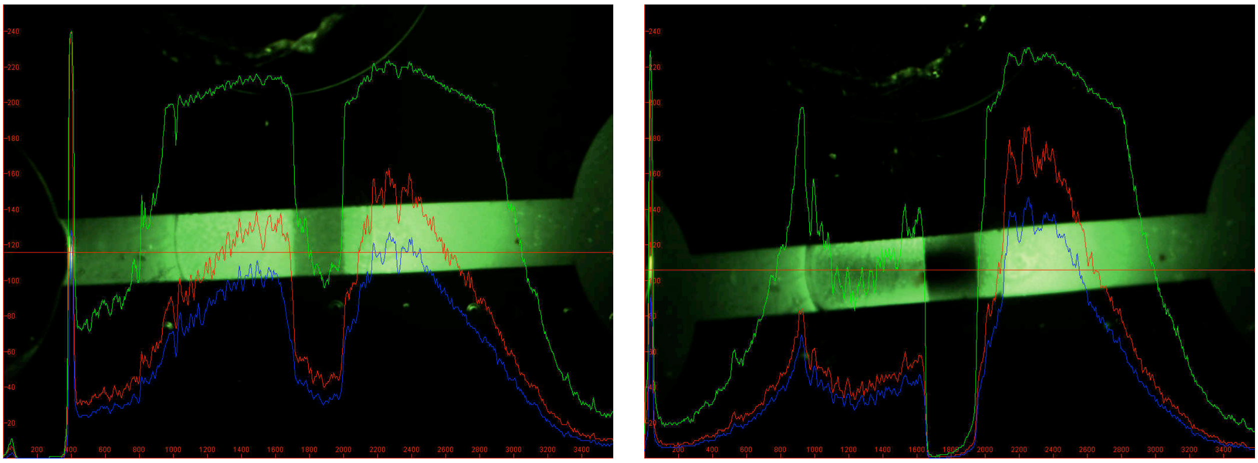

Figure 5 Fluorescence image at valve part
(Left) Open the valve. (Right) Close the valve. Fluorescence intensity at the valve member was half value of fluorescent intensity of a microfluidics channel. This result conform to a channel depth. Fluorescence intensity decreased to 0 when applied pressure to a pneumatic channel and the fluorescence intensity recovered after pressure release.

thickness and channel depth.

This valve has possibilities of functional advancement improvement in channel shape and dimensions such as depth, thickness and width.

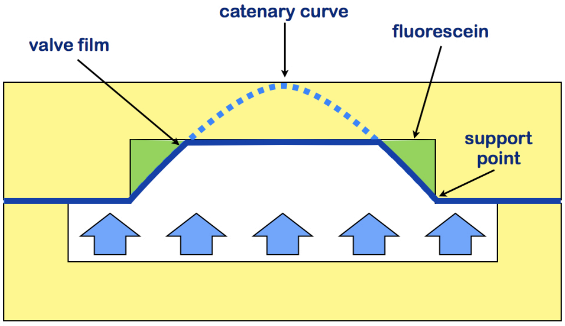

Figure 6 Model of film displacement
Film is subject to homogeneous force from the side of pneumatic channel when valve open, and displaced to catenary cuve.

A new technology and knowledge are able to be learnt and I got a valuable experience to communicate with people in foreign countries through this program. There are various nationalities in the laboratory, and the story of each country was able to be heard. People met while this program are familiar with the history, the culture, and locality of the their home country because many country are closed up in Europe and those countries have many bordering countries. They express a strong interest in another country including Japan. They often asked me about Japan and my home town, I was stuck for an answer and unsure about my answer, I diserned that I don't know about my country, at the same time, I felt embarassed about that.I will break my neck to communicate to foreign people with confidence.