Vertical Micromirror Fabrication by X-ray Lithography for Single Mode Optical Fiber Switching Applications

R. Chimchang, R. Tongta, R. Phatthanakun

***Abstract*—**Inthis paper, design and fabrication of vertical micromirror for optical switching applications of single mode optical fibers are proposed. The structure of micromirror will be created from negative photoresist (SU-8) on X-ray lithography using X-ray from synchrotron light source. The properties of X-ray from synchrotron light source are high-energy electrons which can construct materials that have a high aspect ratio. In addition, the technique of gold coating of reflective material has been used for change direction of light between two pairs of optical fibers. At a wavelength of 1310 nm with minimum average loss of 5.305 dB is obtained.

***Keywords*—**vertical micromirror, negative photoresist,X-ray lithography

I. Introduction

NOWADAYS,optical communication through fiber optic is very popular because it can send data, at high speed, to a very long distance while using a few repeaters. Optical signal in fiber optic has less attenuation compare to electrical signal. In addition, stealing signal from optical fiber system is difficult, so it is the most widely accepted and used. Generally, optical fiber communication is a point to point connection. If we want to communicate from point to multipoint, we have to use more optical fiber line. For this reason, thereisa fabrication device thatacts as alightswitchin order to reducethe number offiberoptic cablestoa minimum. For all of these reasons, we decided to study about fabrication of vertical micromirror using X-Ray lithography technique for optical fiber switching.

Vertical micromirror placed at 90 degree on a chip's surface are highly interesting in terms of micro-optical systems. Installation of optical fiber and laser diode in parallel with plane of the chip is not difficult [1]. On the otherhand, making of high quality optical fiber micromirror is very challenging. For these reasons, plenty of making techniques are made.

Micro-Electro Mechanical system (MEMS) is a very small device in micrometer or one of a million of meter. It is composed of electric part to move another part which use some mechanical system to move. This system can be fabricated by integrated circuit technology, growth technique, etching technique and lithography technique.

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Micro-Electro-Mechanical system is the modern technology and has been continuously popular. It is interested and widespread all around the world due to the demand of small, inexpensive and high-performance devices. This technology has been utilized in various fields. Automotive technology is used MEMS to creating speed metering devices and pressure metering devices. In medical technology and biotechnology is used MEMS to produce different types of sensors and actuators and in the telecommunications technology is used MEMS to produce manufacturing devices in optical communications.

II. UV Lithography, X-ray lithography and sputtering process

A. UV Lithography process

Lithographyprocess is a chemical process to reproduce pattern from the original pattern, which is in opaque lines, to a flat surface [2].It may create pattern in flat surface materials. In reproduction process, we use chemical called photoresist to reproduce the pattern. The chemical property of photoresist will change when the light is exposed on it. Photoresist can be divided into two types. Positive type photoresist will be featured when the light hits in some areas where we can wash it by using developer solution and there will be left only area where the light is not affected. Another type is negative type photoresist, its properties are in contrast to the positive type, unexposed area can be washed by developer solution and then it will be left only the exposed areas. According to the properties of two types of photoresist, we can create patterns for UV lithography process in two ways depending on the type of photoresist. The light projecting to photoresist is the light in ultra-violet (UV) range. The concise overview of lithography process can be explained in Fig. 1comparison chemical property between positive and negative photoresist.

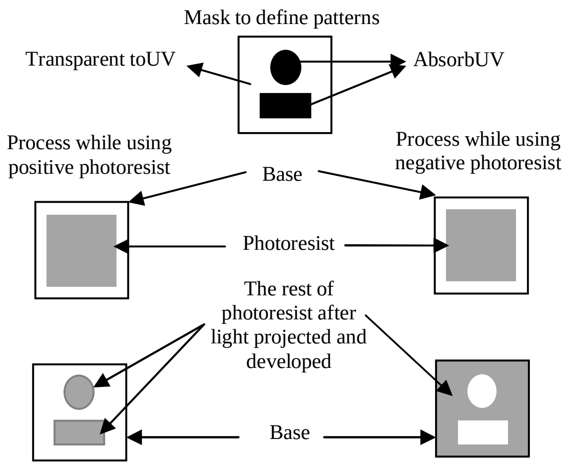

Fig. 1 Reproducing patterns by using lithography process

B. X-rayLithography process

Anotherprocess used in this research is X-ray lithography process which is in the same way aslithography process but the difference is the process using light in X-ray range instead of UV range [3].Moreover, the properties of X-ray obtained from synchrotron source are in high energy. Thus, we can create 3D patterns in high aspect ratio.We can coat photoresist more than 1 millimeter thick, and we are able to create patterns in width of 30 micrometers.So, this process is suitable to produce micro-electro-mechanical system products.

III. Fabrication of X-ray Mask and Creating Micromirrors Structure

InX-ray lithography process, the important factor which has high effects to the process is the X-ray mask since it acts like original patterns. In lithography process using UV, original patterns or mask are the patterns in opaque ink form area situated on transparent material like transparent film or glass. In case of X-ray mask, patterns in opaque ink can't absorb X-ray.So patterns are in the form of material, which well absorb X-ray, and have to be on a high performance transparent material as well. Generally, we use absorber material such as gold lead or silver, its good properties to absorb X-ray, to be patterns placed on a thin graphite sheet or on transparent film in X-ray transparent type.

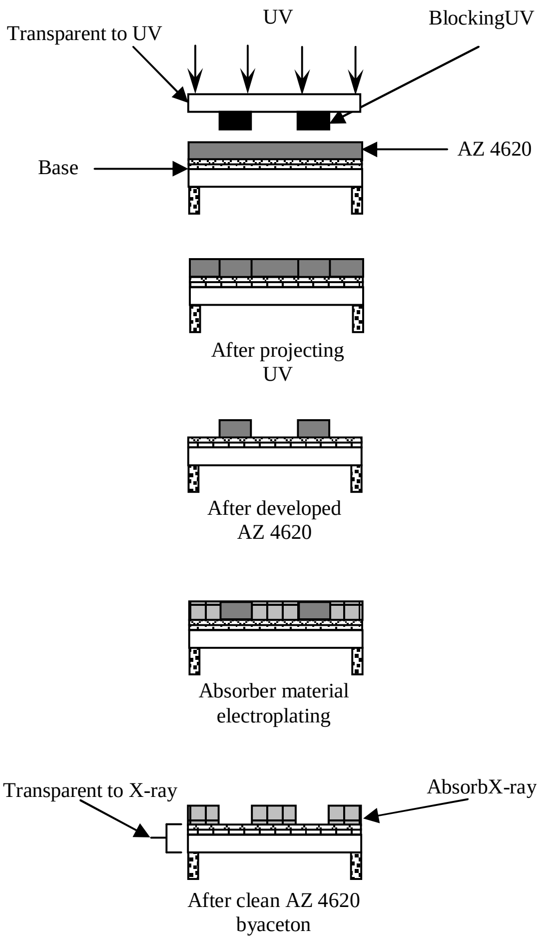

Fig. 2 Cross section of reproducing patterns by UV lithography process for producing X-ray mask

A. Fabrication of X-ray mask

Transparent film was attached by copper ring using epoxy glue. When the glue dried out, cut the transparent sheet by the edge of copper ring, and then coat the sheet with titanium and silver using evaporation procees.

Positive photoresist was spin coating (AZ 4620) on transparent sheet coated with metals. Project UV through photo mask, develop by using photoresist solution AZ developer. The concise overview of UV lithography process for producing X-ray mask is explained in Fig. 2. The piece is passed absorber material electroplating and then clean it by acetone. We can get an X-ray mask as in Fig. 3 and 4.

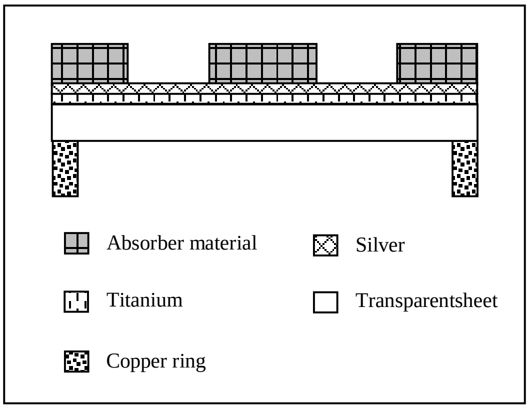

Fig. 3 Cross section of X-ray mask

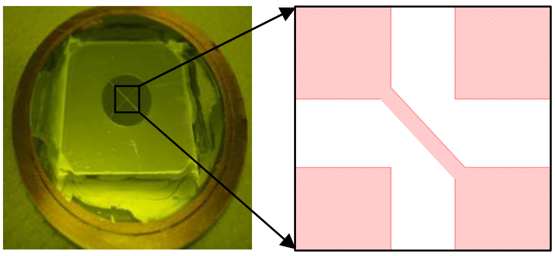

Fig. 4 X-ray mask

B. The process of creating micromirrors structure

Prepare a 1”x1” glass. First, clean and then coat it with titanium. Spin coat with negative photoresist (SU8 2100) by spinner machine at 500 rpm for 5 seconds and at 1500 rpm for 30 seconds respectively. Then bake it in oven at 95°c for 2.30 hours and let it cool down in the oven. Project X-ray to the piece through X-ray mask and bake again at 95°c for 30 minutes and let it cool down in the oven. Develop the piece by SU-8 developer solution and bake again (Hard bake) at 95°c for 30 minutes. The piece is coated thin gold film by sputtering machine at base pressure 5.15×10^{-4} torr, operate passure 1.20×10^{-2} torr and power 100 watts for 60 seconds. So it acts as reflective glass. The concise overview of X-ray lithography process is explained in Fig. 5. Finally, we can get a micromirror as shown in Fig.6 and 7.

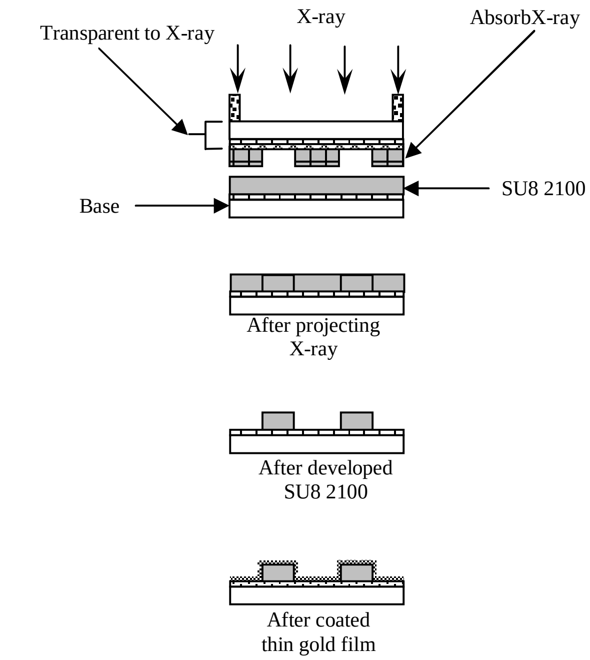

Fig. 5 Cross section of reproducing patterns by X-ray lithography process

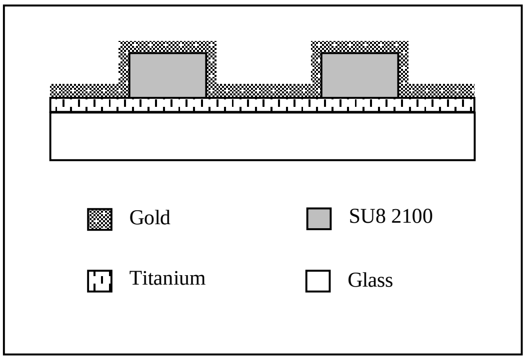

Fig. 6 Cross section of micromirror structure

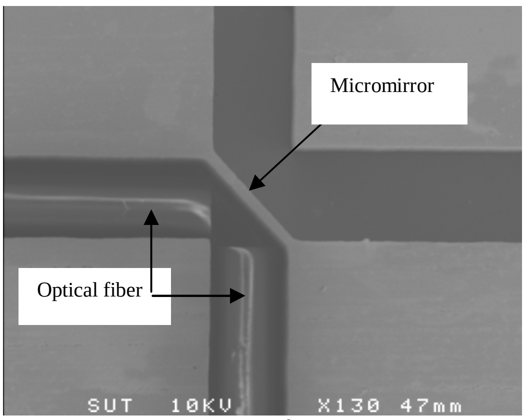

Fig. 7 Structure of micromirror

IV. Result and Measuring Result

After measured the structure of produced micromirror, it was measured 234 micrometers thick, 36 micrometers wide and 184 micrometers long. The groove placing optical fiber was measured 138 micrometers for wide.That was the transmission of the light through the micromirror's structure produced from negative photoresist (SU-8). A 1310 nanometer wavelength light source were projected through an optical fiber line and to another line is receiver. Two line are placed at 90 degree together. The end of these lines plug into LightwaveMultimeter (Fig. 8). After we measured 20 times, we have found that the average loss of signal is 5.305 dB.

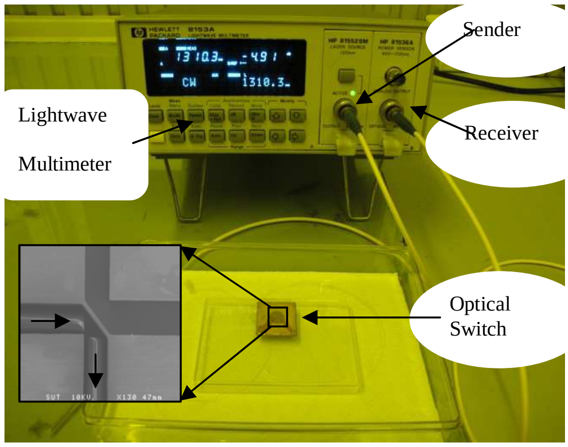

Fig. 8 Transmission of the light test

V. Conclusion

This paper proposed steps of micromirror fabrication for single mode optical fiber switching. The structure of micromirror is produced from negative photoresist (SU-8) by X-ray lithography process, then coated with thin gold film to reflect the light, and changed the direction of the light between optical fiber lines. After measured micromirror, it is 234 micrometers thick, 36 micrometers wide and 184 micrometers long. The groove to place optical fiber is measured 138 micrometers width, which is a little bigger than a 125 micrometers diameter optical fiber. When using light source which has 1310 nanometerswavelength to send data through an optical fiber line and use another line, placed at 90 degree to the first line, to a receiver. The end of these 2 lines areplugged into the lightwavemultimeter. The result, the average loss of signal is 5.305 dB.

Problems and obstacles occurred during the test is deviation of original patterns so the size of produced piece is not conformed to our design. The problems were caused by insufficient size of the groove to place optical fiber make placing the optical fiber line at the proper angle.

The next step will focus on electrostatic comb drive actuators from X-ray lithography process controlled by electrostatic. These electrostatic actuators will be the moveable micromirror driver moving into the light path to optical switching and moving out when optical switching is not necessary.

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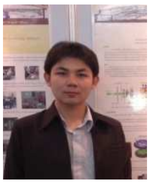

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