MD4
4:45pm - 5:00pm

An Out-of-Plane Polysilicon Actuator with a Smooth Vertical Mirror for Optical Fiber Switch Application

Makoto Mita, Daisuke Miyauchi*, Hiroshi Toshiyoshi and Hiroyuki Fujita
Institute of Industrial Science, The University of Tokyo
7-22-1 Roppongi, Minatoku, Tokyo 106-8558 Japan
* Address: R&D center,TDK Corporation.
15-7 Higashi Owada 2, Ichikawa,Chiba 272,Japan

INTRODUCTION

Micromachined optical switches are under intensive study for optical communication networks. Some of them require special high-aspect-ratio technologies such as LIGA[1] and deep RIE[2]. Some are a few millimeters in size[3,4]. We have designed a 2x2 micro optical switch which is micro-meters in size, fully micromachined except one step, and has a simple mechanism because of electrostatic actuation.

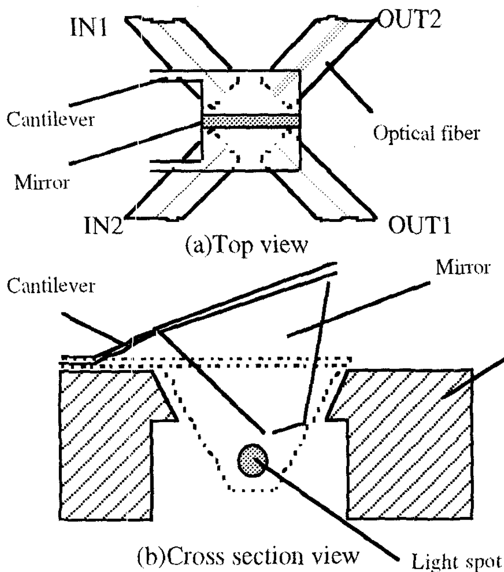


Fig.1 Device schematics

Fig.1 shows the schematic representation of the switch. It is composed of a plate supported by curled cantilevers, a smooth mirror attached vertically to the plate, driving electrodes, and a trench and grooves in a substrate. When the plate is attracted electrostatically to the driving electrodes, the mirror moves perpendicular to the substrate and reflects the light beams from an input optical fiber(IN1) into an output fiber (OUT2); optical fibers are placed in grooves etched in the backside of the substrate. By removing the electrostatic force, the plate and the mirror move up and the light beam is directly introduced to a fiber(OUT1).

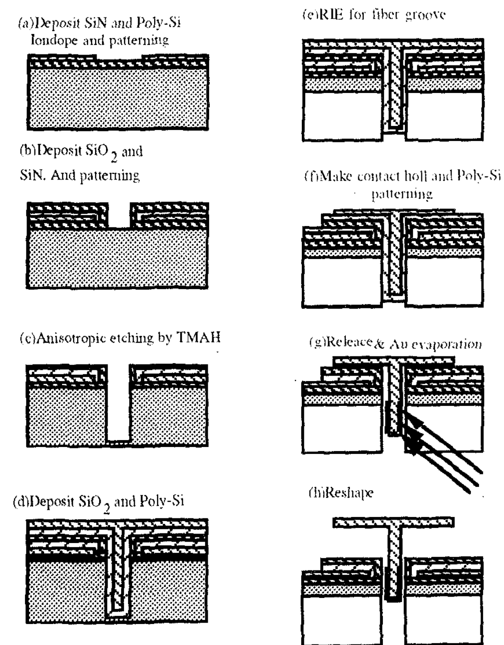


Fig.2 Proposed process flow of optical switch

Fig.2 depicts a possible fabrication process. First driving electrodes are patterned and insulated. The trench was formed by anisotropic wet etching in a (110) substrate and covered by sacrificial oxide. Poly-Si is deposited and patterned in the actuator and mirror. Four grooves are dry etched from the backside. After sacrificial etching, The mirror is metalized by evaporation. Finally, the actuator is raised out-of-plane and held there by plastic deformation caused by Joule heating (reshaping process[5]).

The switch has following advantages:
(1) The distance between fibers can be as close as a few tens of micrometers,
(2) fiber alignment is assured by grooves,
(3) the mirror can be as large as a few

0-7803-4953-9/98$10.00©1998 IEEE

hundreds of microns,
(4) the mirror surface is smooth because it is the replica of a wet-etched (111) plane, and
(5) fabrication can be batch processed except the final reshaping step.

TEST DEVICE

In order to confirm the concept, we have fabricated a test device.

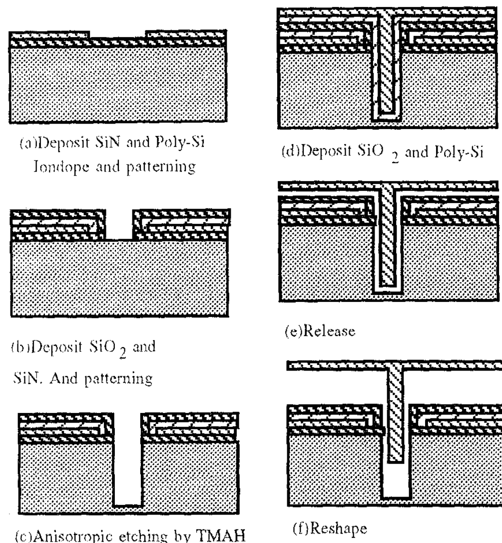
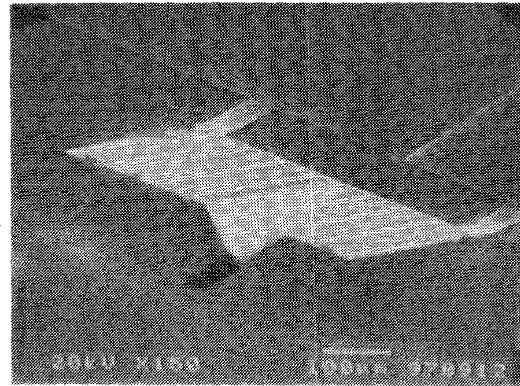


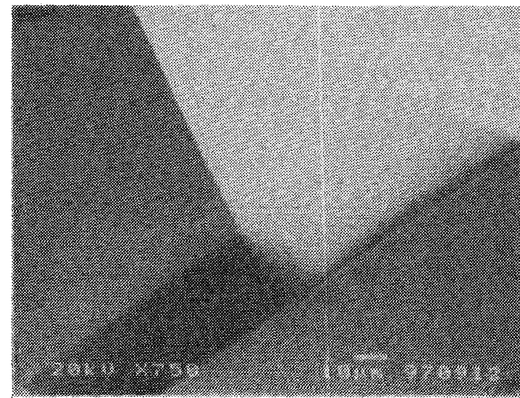
Fig.3 Process flow of the test device

The fabrication process is shown in Fig. 3. First driving electrodes is made by LPCVD of silicon nitride (0.1 um) and Poly-Si (1 um) on Si(110) substrate (300 um). Then patterning the nitride and Poly-Si by RIE. After the electrode is covered by silicon oxide(1 um) and silicon nitride(0.1 um),the trench is formed by anistropic etching in TMAH solution. It is 30 um wide, 500 micrometers long and 170 um deep. Sacrificial silicon oxide (4 um) and poly-Si(1 um) are deposited by LPCVD. Then, the poly-Si is P-ion doped and patterned by RIE to form the plate and cantilevers. After etching the sacrificial oxide by HF, the plate and mirror are raised out-of plane and held there by plastic deformation. The reshaping is done with a current of 20 mA and current duration of 1 minutes.

SEM pictures are shown in Fig. 4. The plate is 500 um square and 1 um in thickness. Cantilevers are 400 um in length and 50 um in width. The height of the plate edge is 100 um from the substrate. The characterization of the actuator is under way and will be given in the presentation. Using a simple cantilever which was reshaped, the life-time test was carried out. We did not observe any failure even after one million cycles of bending operation with electrostatic force.



(a)Reshapedcantileverwith mirror



(b)Close up view of mirror and trench

Fig.4 SEM micrograph of the test device

References

[1] J.Mohr,et al."Micro Optical Switching by Electrostatic Linear Actuators with Large Displacements" Proc,Transducers-93, pp.120-123

[2] C.Marxer, et al."Vertical Mirrors Fabricated By Reactive Ion Etching For Fiber Optical Switching Applications" Proc. MEMS-97, pp.49-54

[3] R. A. Miller, et al."An Electromagnetic MEMS 2x2 Fiber Optic Bypass Switch" Proc. Transducers-97,pp.89-92

[4] Shi-Sheng Lee, et al."Surface-Micromachined Free-Space Fiber Optic Switches With Integrated Microactuators for Optical Fiber Communication System" Proc. Transducers-97,pp.85-88

[5] Fukuta, et al."A RESHAPING TECHNOLOGY WITH JOULE HEAT FOR THREE DIMENSIONAL SILICON STRUCTURES" Proc. Transducers-95, pp.174-177