行政院國家科學委員會補助專題研究計畫成果報告

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光纖通訊應用之微光機電系統元件

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計畫編號：NSC 90-2215-E-002-031-
執行期間：　90年　8月　1日至91年　7月　31日

計畫主持人：黃榮山

計畫參與人員：朱大舜、張朝森

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- □赴國外出差或研習心得報告一份
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- □國際合作研究計畫國外研究報告書一份

執行單位：國立台灣大學應用力學研究所

中　華　民　國　91年　10　月　31　日

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Abstract

We report on a novel switchable corner micromirror for wide free-space optical applications. The corner mirror, composed of two mutually orthogonal reflective surfaces, may reflect incident light beam at any angle back to its incoming direction. In this report the corner micromirrors are able to be batch fabricated. Each micromachined corner mirror is constituted by three elements: a vertical mirror, a movable horizontal mirror, and a bottom electrode. Incorporated with a grating and other optical components, the new device may provide simultaneous wavelength selection in free space and switching function for wavelength as well as intensity. Thus, the corner micromirror may alleviate alignment problems and simplify assembly procedure.

Ⅰ. Introduction

In the recent years, micro optics has gradually been playing an important role in optical communication, imaging and instrumentation. A corner mirror, composed of two orthogonal surfaces, can be used to reflect incident light back to its incoming direction. In this report a micromachined corner mirrors is first reported to manipulate light beam in free space. With the merits of MEMS technology in miniaturization and batch fabrication [1], the corner micromirror allows to provide actuation on one of the reflective planes, causing destruction of preset orthogonal planes. In a sense of optics, a switchable micro corner mirror is thus achieved as depicted in Fig. 1.

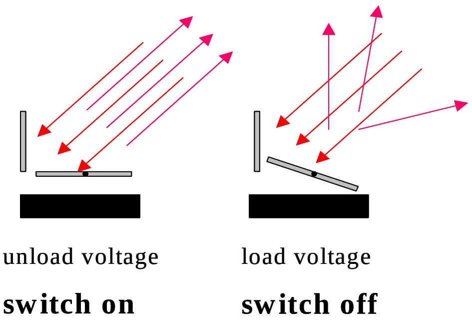


Fig. 1 The concept of an optically switchable micro corner mirror

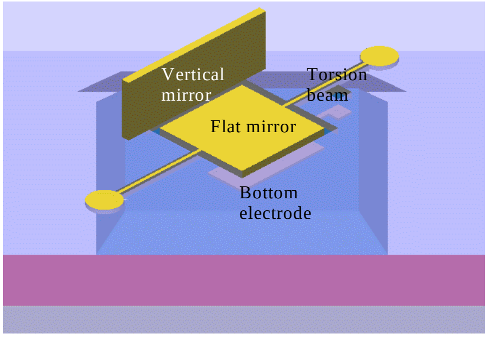
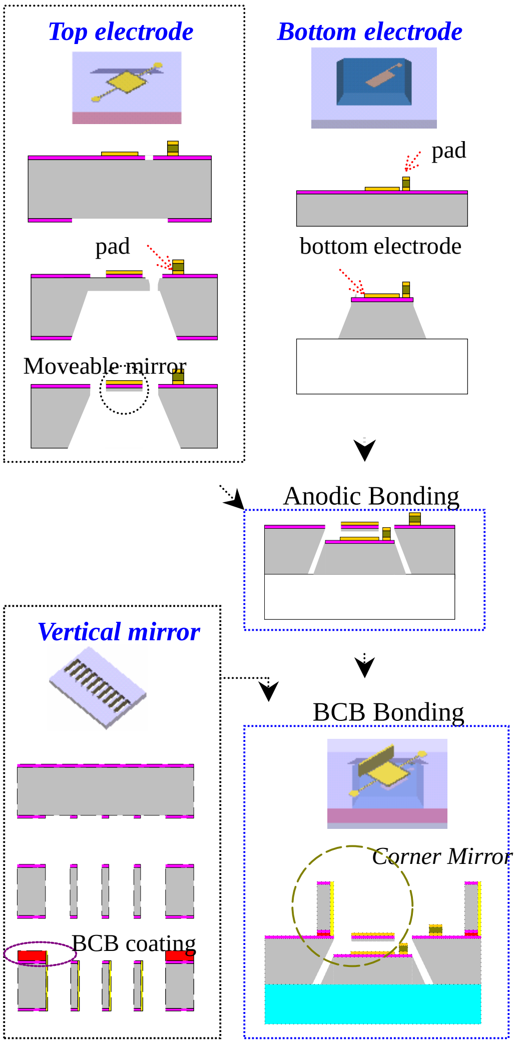


Fig. 2 The schematic of a switchable micro corner mirror

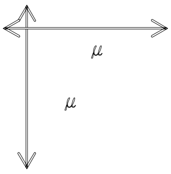
Ⅱ. Fabrication and assembly

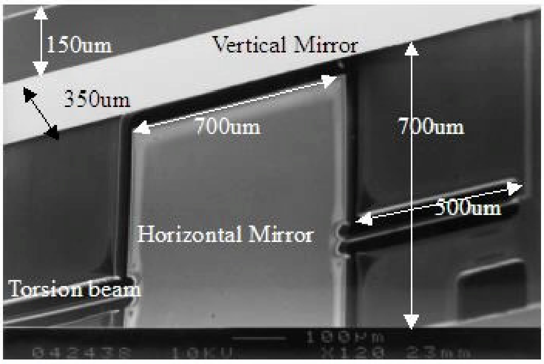
A micro corner mirror requires two orthogonal planes with virtually flat and reflective surfaces. Fig. 2 demonstrates the schematic drawing of a switchable micro corner mirror that is constituted by three elements: a vertical mirror, a movable in-plane mirror, and a bottom electrode.

The switchable micro corner mirror is able to be batch fabricated. Fig. 3 shows the entire fabrication and assembly processes. In such a fabrication, all the microstructures are individually bulk-micromachined and then formed together in assembly. Meanwhile, the vertical mirror is made with a Si (110) wafer as the in-plane mirror and bottom electrode are anisotropically micromachined from Si (100) wafers.



To gain mirror reflectivity and electrode conductivity, the thin gold films are evaporated onto the mirror surfaces and electrodes. In the first assembly procedure, the anodic bonding of both the in-plane mirror and bottom electrode onto the same glass carrier was used to form the actuated in-plane mirror. Meanwhile, the gap for electrostatic actuation is critical, which determines a tilted angle and applied voltage. Although the gap control can be achieved by the sacrificial-layer technique in surface micromachining, especially, the assembly required for sophisticated or out-of-plane structures still remains challenge. In gaining the precise gap beyond the achievable sacrificial thickness, the fabrication of both in-plane mirror and the bottom electrode were made from the same wafer. Additional dry etch of the bottom electrode to a required depth was used.





Ⅲ

The opto-mechanical property of mirror flatness was inspected through the instrumental interferometer, WYKO MHT III. The fabricated in-plane mirror in size of 700 μm×700 μm × 12 μm is more even critical in radius of curvature than the 150 μm-thick vertical mirror. Fig. 6 shows the result of 34.31 mm in radius of curvature. The curvature radius becomes larger as it increases thickness.

In the simple optical setup of Fig.7, the relationship between loading voltage and rotation angle of the electrostatically switchable micromirror can be obtained. As shown in Fig. 8, the pull-in voltage was measured around 110 volt in which the critical angle was approximately 2^{o}. In addition, Fig. 9 demonstrates its resonance at 2.9 kHz in a close agreement with the calculated resonance of 3.2 kHz.

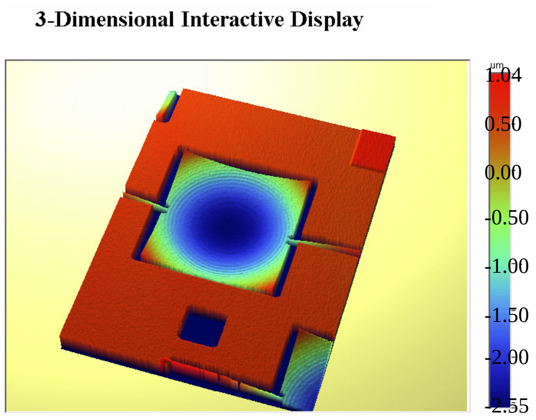


Fig. 6 The 3D surface profile image of an in-plane actuator.

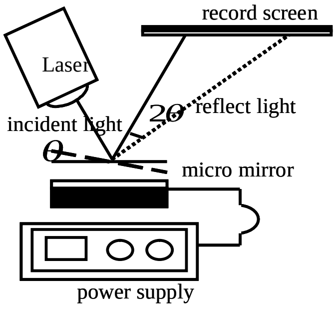


Fig. 7 The optical setup which is used to measure the relationship between driving voltage and rotation angle.

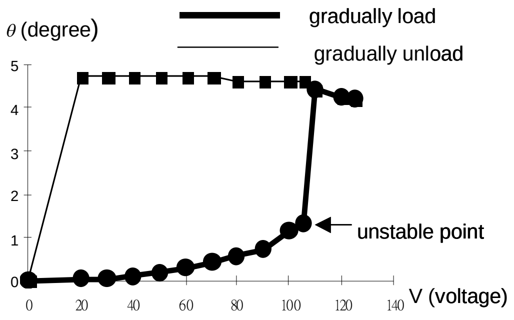


Fig. 8 The relationship between rotation angles of in-plane mirror and driving voltage diagram of actuator

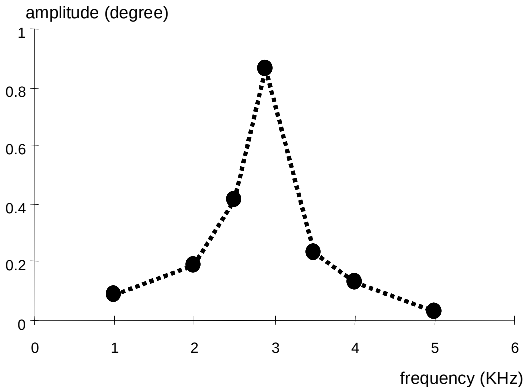


Fig. 9 The resonant frequency measurement of actuator at forced vibration by 75V driving voltage

To characterize its optical response under the mechanical actuation, Fig. 10 shows the optical setup that the switchable corner mirror is placed in the light path. As the corner mirror is actuated, the optical response can be detected in an optical power meter.

The experiment was conducted in a range of 50 – 125 volt. In the actuation of 100 volt as shown in Fig. 11, the fall time and rise time in optical response are approximately 1.5 ms and 2 ms, respectively. The result corresponds to a usual micro mechanical dynamic behavior in a range of millisecond.

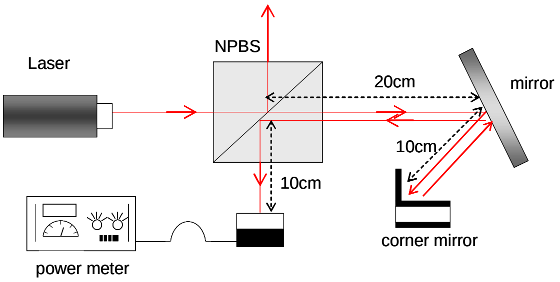


Fig. 10 The optical setup in measuring optical response in an actuated micro corner mirror.

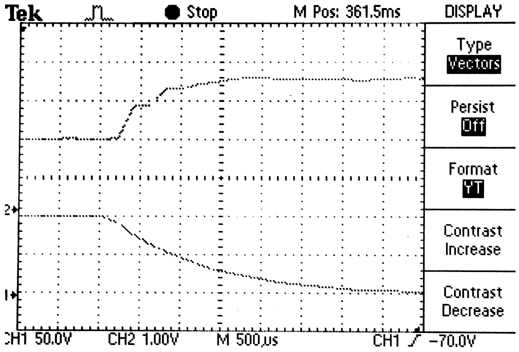


Fig. 11 The optical response (upper signal) versus electrical input (below signal) of 100 volt f cases (a) fall time of 1.5 ms. (b) rise time of 1.25 ms.

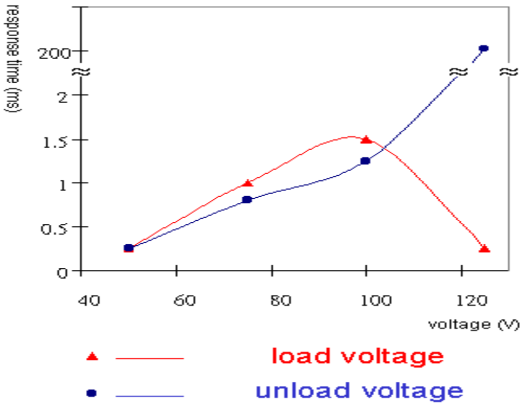


Fig. 12 Various fall and rise times in corresponding applied voltages.

Fig. 12 demonstrates the device optical response in different driving voltages. As the driving power is increased, the response requires longer time to stablize the in-plane mirror inertia-induced vibration. However, while the applied voltage was increased up to 125 volt, the response time was significantly reduced. The in-plane mirror was found snap-down to the bottom electrode, a situation that the actuation was no longer reversible beyond the pull-in voltage of 113 volt. Corresponding to the voltage unloaded, the release of capacitance requires longer discharge.

Ⅳ. Conclusion

The newly switchable bulk-micromachined corner mirror has been successfully presented. The opto-mechanical property of mirror flatness was investigated, which would be critical in beam size property. Static and dynamic characterization of bulk-micromachined corner mirror have been experimentally conducted, which demonstrated the pull-in voltage of 113 volt and its resonance at 2.9 kHz.

Reference

[1] Steffen Kurth *et al.*, "Silicon Mirrors and Micromirror s for Spatial Laser Beam Modulation", Conf. on Solid-State Sensors and Actuators, IEEE (1997), pp. 81-84.

[2] T.S. Chu *et al.*, "A New Addressable Corner Micromirror Array for Free-Space Optical Applications", IEEE/LEOS Optical MEMS, Lugano, Swizerland, pp. 45-46, Aug. 2002.

[3] T.-S. Chu, A New Addressable Corner Micro-mirror Array for Optical Applications, Master thesis, National Taiwan University, 2002