內視鏡用熱動式微致動器的設計與製作(II)

Design and Fabrication of Thermally Driven Microactuators for Endoscope

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一.中文摘要

本計畫製作出兩種利用微熱致動器偏轉微鏡面的結構，第一種可旋轉微反射鏡致動機構是利用第一年所發展的線性微馬達，配合立體接頭與連桿，把微反射鏡由平面 0 度位置驅動至垂直 90 度位置，可使反射鏡在 90 度內調整。此微致動機構是以 MCNC 之三層多晶矽加工技術（MUMPs）製作。第二種可旋轉的微反射鏡致動機構主要包括一個作為微鏡面的的傾斜平板，一個用來承載此平板的一個空心圓環，以及用來推動空心圓環的電熱式側向位移致動器，以使此傾斜鏡面將可做三百六十度之旋轉運動。此結構是以雙層多晶矽面微細加工技術製作，並利用熱塑性，從矽晶片平面作出立體的微反射鏡結構。

英文摘要

In this project, two types of thermal microactuators integrated with micro mirrors have been designed and fabricated.. The first-type rotary micro mirror is base on the thermally driven linear micro motor developed in the first year to incorporate with micro hinges and linkages. Then the micro mirror is driven from horizontal position to vertical position. This micromechanism is fabricated by three-layer polySi process MUMPs (Multi-User MEMS Process) at MCNC (Microfabrication Center of North Carolina). The second type of rotary micro mirror is mainly composed of three parts: a inclined plate served as the micro mirror, a hollow disk used to mount the plate, and the laterally driven micro actutators to rotate the hollow disk. The fabrication of this micromechanism is conducted at SRC by two-layer polySi process. The inclined micro mirror is bended out from silicon wafer automatically due to the thermal plastic property.

二.計畫緣由與目的（Introduction）

Micromirrors attract lots of attentions in Micro-Electro-Mechanical Systems (MEMS) for possible application in minimizing optical device. Different types of micromirrors have different applications. For example, a stationary

micromirror can be used as a light or wave guide in optical instruments by reflecting light or wave to the desired direction. Moreover, a movable micromirror can act as an optical switch. For a moving micromirror with high frequency, it can be used as an optical signal modulator. When lots of torsional mircromirrors are set in an array, they can be applied to a printing or projection display device.

A stationary micromirror usually contains a reflecting surface which can be easily made by anisotropic wet etching of silicon. For a movable micromirror, it needs some actuation mechanisms. Selecting proper actuation mechanisms depends on its application. Here we are interested in designing a micromirror with large rotating angle to reflect light into a wide range at low frequency.

In this project, two micro mechanism to rotate micromirrors large angles (90 and 360 degrees) at a low frequency are proposed. The rotating axis of the mirror is inclined to the mirror surface. When the micromirror rotates, the light injected along the rotating axis to the micromirror can be reflected to the periphery of the micromirror. The micromirror can be used in the endoscope or other optical scanning applications.

三.研究方法

The schematic diagram of the first-type design is shown in Fig.1.

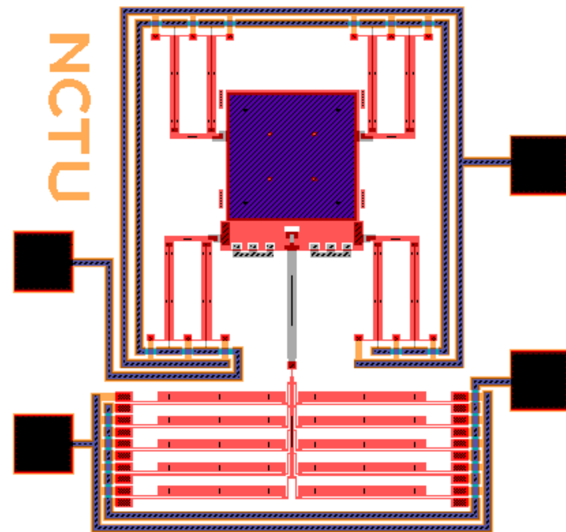

Fig.1 Schematic diagram of the first-type micromirro actuating mechanism

The device consists of a micromirror, a lateral driven thermal-actuator array, four pair of vertical thermal-actuator, and a locking mechanism that has an I-shaped tether beam and a T-shaped hole that is extended from the bottom of the micromirror. In order to rotate the micromirror along a fixed axis, a set of hinges/torsion-bars was designed according to specific requirements. The self-assembly process is started by actuating the vertical thermal actuators which are placed under the micromirror. The vertical force lifts the micromirror out of the plane of substrate such that the I-shaped tether beam is able to slide into the T-shaped hole to create the necessary lock-up condition. The lateral driven thermal-actuator array that is attached and aligned with I-shaped tether beam is then activated to push/poll the micromirror and cause the micromirror to rotate. In analysis, a post-objective scan system is used to design the size of micromirror from

$$\frac{1}{d} \approx \frac{\Delta}{\lambda f}$$

where d is length of micromirror, **λ** is the wavelength of laser, f is the focal length of lens, and △ is size of spot.

Also, by simple mechanical analysis, the lift angle of the micromirror is determined.

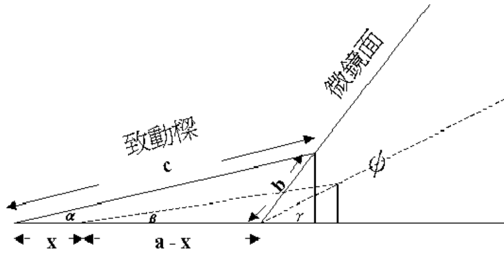

Fig. 2 Lift angle determination

$$〃 = W - X$$

$$= \cos^{-1}\frac{c^2 - a^2 - b^2}{2ab} - \cos^{-1}\frac{c^2 - (a-x)^2 - b^2}{2(a-x)b}$$

For the second-type micromirror actuating mechanism, the design concept is shown in Fig. 3. As the diagram shown, the inclined micromirror with rotating motion is based on the vibrimotor structure. A thermally driven actuator with lateral motion is employed to rotate the hollow disk. As the hollow disk rotates, so the inclined micromirror on the disk. In order to incline the micromirror, the technology of bend 3D structure out of silicon wafer plane is adopted. The polyimide is employed in our design. The ployimide is put on the plate between the micromirror and the hollow disk. When the polyimide is heated, it shrinks to tilt the micromirror.

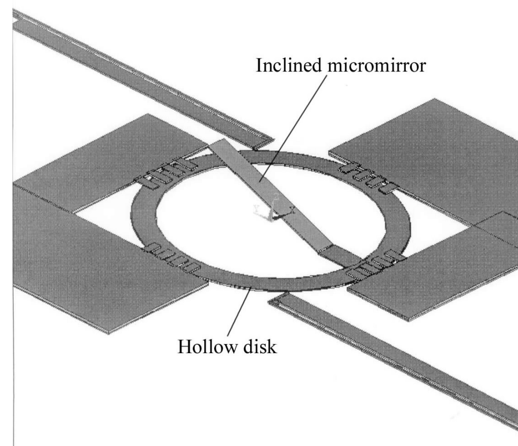

Fig. 3 Design concept of the second-type micromirror actuating mechanism

四.結果與討論

Figure 4 shows the fabricated result of the first-type micromirror actuating mechanism by using MUMPs. The rotating angle is found to be around 40 degrees. The mechanism can operate hundreds of hours without failure. However, friction is the critical factor.

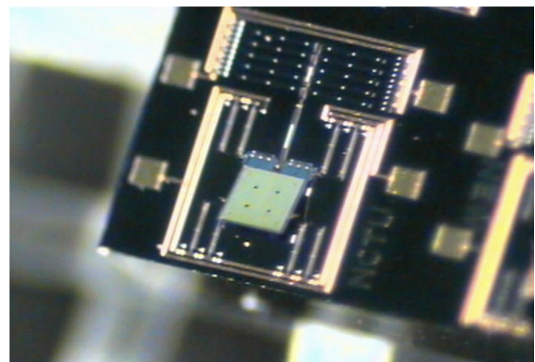

Fig. 4 Fabricated result of the first-type actuating micromirror

The fabricated results of the second-type micromirror actuating mechanism is shown in Fig. 5. The microactuator was tested in air by applying an ac triangular

voltage. For 10 V input voltage, the linear displacement of the microactuator is about 10 μm. Because the gap between the micro actuator and the hollow disk was too wide, the microactuator did not contact the hollow disk. Besides, it was observed that one microactuator was not enough to actuate the hollow disk. The gap width must be reduced to generate a larger output force.

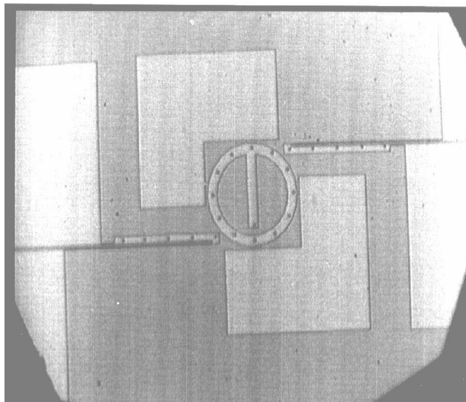

Fig.5. Fabricated result of the second-type micromirror actuating mechanism

五.參考資料

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