WB4
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Two-Dimensional Optical Scanner with Large Angular Rotation Realized by Self-Assembled Micro-Elevator

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Two-dimensional (2D) optical scanners with large-area mirrors and large angular rotation are of great interest for applications in display, printing, optical scanning and sensing, optical data storage, and free-space optical links between satellites. The Micro-Electro-Mechanical System (MEMS) technology is very attractive to reduce the size, weight, and complexity of the optical scanners. Several bulk- [1,2] and surface-micromachined [3,4] 2D scanners have been reported. To achieve large angular rotation for large-area micromirrors, the mirrors need to be suspended high above the substrate. This requires the use of complicated processing steps such as thick sacrificial materials or wafer bonding with bulk-micromachined structures.

Previously, we reported a novel micromechanical structure called Micro-Elevator by Self-Assembly (MESA) [5] that can raise the surface-micromachined plates to several hundred micrometers above the wafer surface. In this paper, we report a novel 2D scanner realized by the MESA technology. Large optical deflection angles (> ± 14°) have been achieved for large-area mirrors $400 \times 400\ \mu m^2$ without employing thick sacrificial layers.

The schematic structure of the MESA-based 2D scanner is shown in Fig. 1. The micromirror is attached to a pair of suspended frames through two sets of orthogonal torsion beams. It can be rotated around two axes by applying electrostatic force between the mirror and the quadrant electrodes on the substrate. The outer frame is connected to four side-support plates by microhinges. By pushing the four microactuator plates inwards simultaneous, the center plate can be raised above the substrate. Its height can be controlled by programming the in-plane microactuators connected to the MESA. Figure 2 shows the scanning electron micrograph (SEM) of the 2D scanner. It is fabricated by the standard three-layer polysilicon surface-micromachined process offered by MCNC [6]. The micromirror used in this experiment has an area of 400 μm × 400 μm. Previously, micromirrors as large as 5 mm × 5 mm have been successfully suspended by the MESA structure. By applying bias to electrode 1 and 2, the mirror is rotated around the Y-axis, as shown in Fig. 2(a). If the bias is switched to electrode 2 and 3, the mirror is rotated around the X-axis as shown in Fig. 2(b). Independent scanning around two axes has been verified. The performance of the 2D scanner is characterized by shining a HeNe laser beam on the micromirror. Figure 3 shows the far-field patterns of the steered optical beams. The optical deflection angle versus applied voltage is shown in Fig. 4. A maximum deflection angle of ± 14° has been achieved. A pull-in voltage of 70 V is measured at 14° scan angle. The voltage can be reduced by employing thinner torsion beams. The resonant frequency of the scanner is measured to be 1.5 kHz.

In summary, a novel 2D scanner with large mirror area and large angular rotation has been proposed and demonstrated. The mirror is supported by the surface-micromachined micro-elevators by self-assembly (MESA). Maximum optical deflection angles of ± 14° and a resonant frequency of 1.5 kHz have been achieved.

Reference:
[1] D. L. Dickensheets, G. S. Kino, "Microfabricated biaxial electrostatic torsional scanning mirror", *Proceeding of SPIE*, vol. 3009, pp. 141-5, 1997.
[2] K.E. Petersen, "Silicon Torsional Scanning Mirror," *IBM J. Res. Dev.* vol. 24, p.631.
[3] L. J. Hornbeck, "Projection displays and MEMS: Timely convergence for a bright future," Proceedings of SPIE, vol. 2639, pp. 2, 1995.
[4] V.R.Dhuler, M. Walters, R. Mahadevan, A. B. Cowen and K. W. Markus, "A novel two axis actuator for high speed large angular rotation", *Proceedings of Transducers*, pp. 327-330, 1997.
[5] L. Fan, M. C. Wu, K. D. Choquette and M. H. Crawford, " Self-assembled microactuated XYZ stages for optical scanning and alignment," *Proceedings of Transducers*, pp. 319-322, 1997.
[6] MEMS Technology Applications Center at Microelectronics Center at North Carolina (MCNC), Research Triangle Park, North Carolina.

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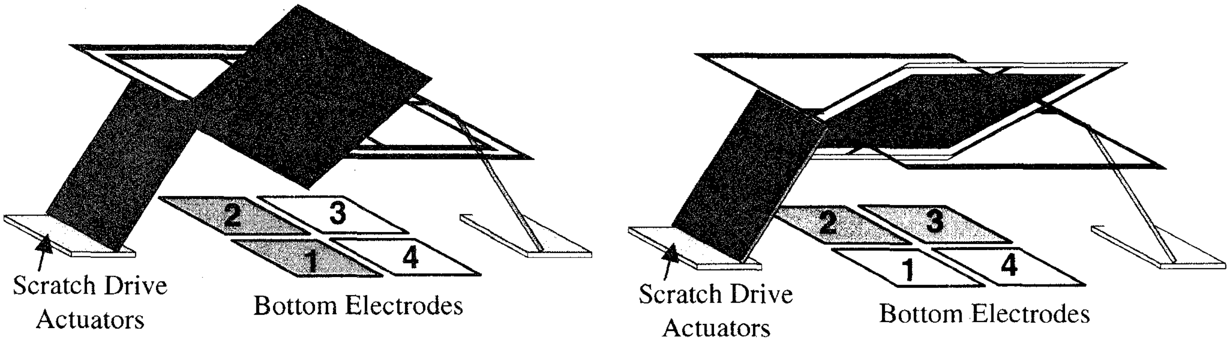

Figure 1: The schematic structure of the MESA-based 2D scanner.

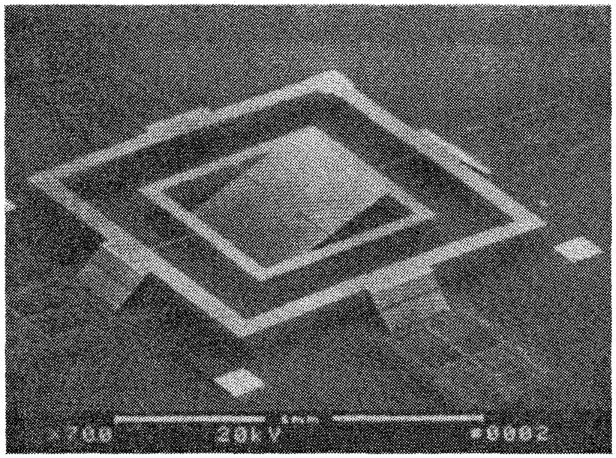

Figure 2(a): The mirror is rotated around the Y-axis

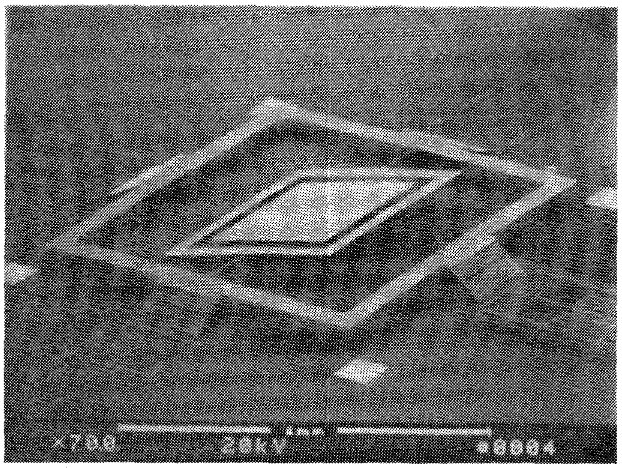

Figure 2(b): The mirror is rotated around the X-axis

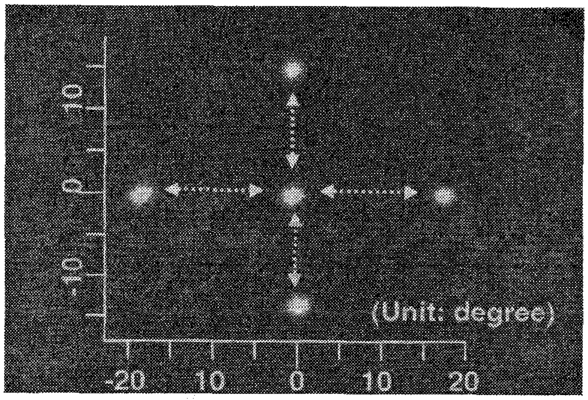

Figure 3: Far field patterns of the steered optical beam.

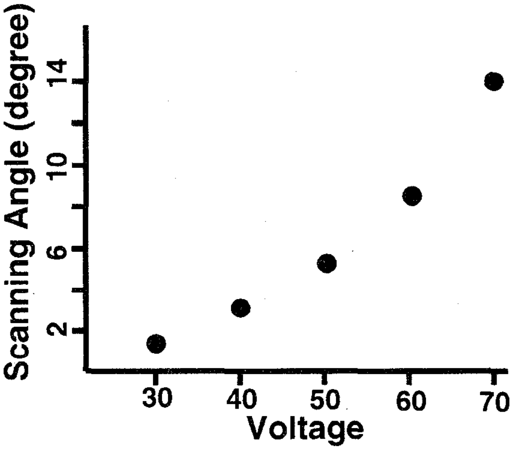

Figure 4: The optical deflection angle versus applied voltage.