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마이크로 CCR구현을 위한 저전압 구동 압전 반사경 설계

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Design of Low Voltage Piezoelectric Actuated Mirror for Micro-CCR

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Abstract - This paper present a piezoelectric actuated mirror with PZT cantilevers, torsional bars and hinges for Micro-CCR (corner cube retroreflector). The actuated mirror with low voltage and large tilting angle is designed and simulated by using FEM (Finite Element Method) simulator (CoventorWare). The tilting angle of actuated mirror is 2.93° at low voltage of 5V

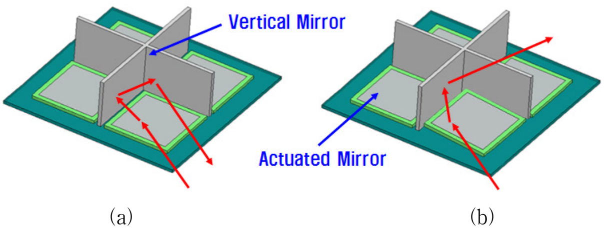
1. Introduction

Recently, there is increasing demand for wireless communication system with low power and small size. The general wireless communication is based on RF or optical techniques. RF transceivers are more complex circuits, difficult to minimize their size and reduce power consumption to the required micro-watt levels. Therefore, optical transceivers are more efficient at low power because of simple circuits; no modulators, active bandpass filters or demodulators are needed [1].

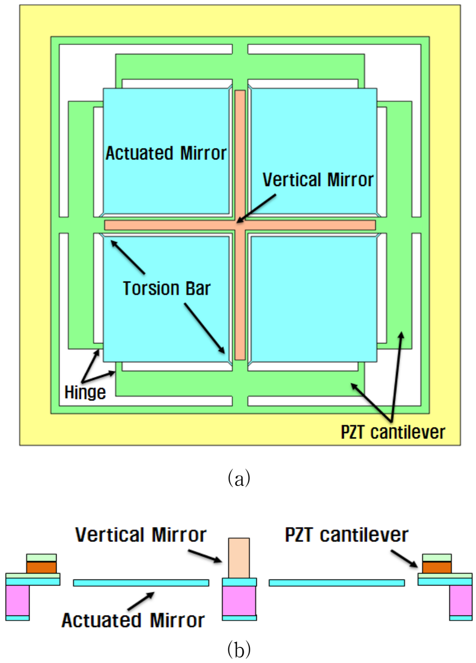
Two compact approaches to free-space optical communication include passive reflective systems and active-steered laser systems. The passive reflective system consists of three mutually orthogonal mirrors including an actuated mirror and vertical mirror as shown Figure 1. This structure is a corner cube retroreflector, or CCR [2]. The transmitter with a CCR may consume minimal power since it transmits data by reflecting external light beam [3]. In off state, the light comes from a quadrant of hemisphere defined by the concave side of the CCR, then the entered light is reflected back parallel to the source as shown Figure 1 (a). If the actuated mirror is tilted as shown Figure 1 (b), the returned light is reflected in the different direction of incident light on state. Moving the actuated mirror in synchrony with information, it can transmit information to the source onto a reflected light using much less power than RF systems.

Previously, the electrostatically actuated mirror of the CCR shows drive voltage range from 7V to 11V, and tilting angle up to 2.58° [4], but has a problem to require a large power [5]. As actuated mirrors for optical communication, reported piezoelectric actuated mirrors show low voltage and power operation compared to electrostatic actuators [6], However, the tilting angle of 0.75° was too low to apply for the CCR

In this paper, we propose a new design approach of piezoelectric actuated mirror with PZT cantilevers, torsional bars and hinges for low voltage of 5V and tilting angle up to 3°. The length of cantilever is as long as the actuated mirror to obtain large bending. The torsional bar and hinge structure allows the proposed actuated mirror to maintain actuated flatness of mirror plate and stably operate on bending of PZT cantilevers.



<Figure 1> Concept of CCR (Corner Cube Reflector) Voltage applying (a) off and (b) on state.



<Figure 2> Schematic drawing of the Piezoelectric Actuated Mirror. (a) Top view, (b) Side view.

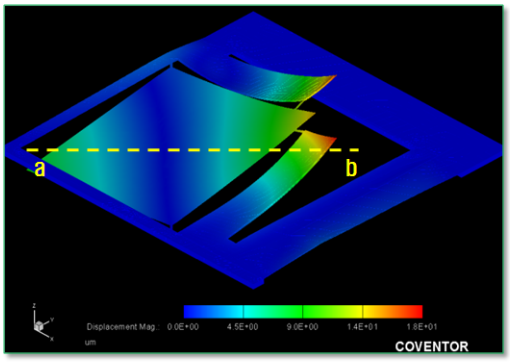
2. Design and Simulation

The proposed mirror structure comprises four actuated mirrors, which are symmetrically rotated and arranged for the four concave sides of the CCR as shown Figure 2. The vertical mirror is attached on plane between the actuated mirrors. The actuated mirror consists of a mirror plate, PZT cantilevers, hinges and torsional bars, respectively. In proposed mirror structure, the actuated mirror is designed with only two PZT cantilevers beside the sides of mirror plate. The PZT cantilever is connected to the edge of mirror plate by the hinge. Two torsional bars are located at the opposite edges of mirror plate to maintain flatness of mirror plate on actuation mode.

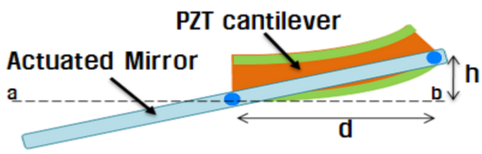
If a voltage is applied to the actuated mirror, a pair of PZT

<Table 1> Parameters of the proposed actuated mirror

	Width	Length
Mirror plate	400μm × 400μm	
Cantilever	80μm	350μm
Hinge	5μm	30μm
Torsional bar	5μm	14μm



<Figure 3> Simulation results at 5 voltage using CoventorWare



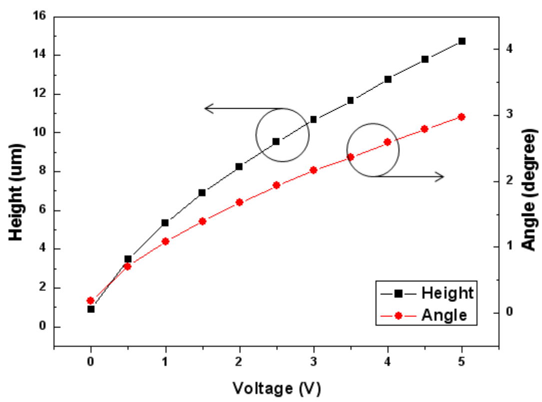
<Figure 4> Operational concept of cross section in the actuated mirror

cantilevers bend upward. The bent cantilevers accordingly lift the mirror plate by hinge, then the actuated mirror tilts up. The more the PZT cantilever bends, the more the tilting angle of actuated mirror is increased.

The mirror plate and the hinge are formed from the low stress silicon nitride layer. And those, Pt, PZT and Ti/Pt, are sequentially deposited on the low stress silicon nitride and etched to form PZT cantilever. Both of Pt layers are bottom and top electrode, respectively.

The designed actuated mirror is operated by applying external voltage at top and bottom electrode of PZT cantilevers. The quadrant of actuated mirror is simulated from 0 to 5 voltage by using FEM (Finite Element Method) simulator (CoventorWare). Figure 3 shows the actuation mode of actuated mirror at 5 voltage. In the simulation, the actuated mirror operates and tilts up on the axis across two torsional bars of mirror edges. The parameters of actuated mirror are optimized to obtain low voltage of 5V and tilting angle of 3° from the simulation. The designed parameters of actuated mirror are summarized in Table 1.

The tilting angle (Θ) of mirror plate can be calculated according to a simple geometrical relationship as $\theta = \tan^{-1}(h/d)$ where d is the half of a diagonal line across mirror plate and h is the actuated height of edge point of mirror plate as shown Figure 4. Figure 5 shows the simulated height at the edge of mirror and the calculated tilting angle of mirror plate respect to applied voltage. Once the



<Figure 5> Simulated height at the edge of mirror and calculated tilting angle of mirror plate as a function of the applied voltage.

voltage is applied in the simulation, the edge of mirror plate is actuated along the black line in this graph. The tilting angles at 0 and 5 voltage are calculated as 0.182 and 2.93° from simulation, respectively. As the simulation result, piezoelectric actuated mirror is operated at low voltage. However, the initial angle of mirror plate is not perfectly flat and the cantilevers are bent upward without voltage.

3. Conclusion

In this paper, we design and simulate the piezoelectric actuated mirror with PZT cantilevers, torsional bars and hinges. The designed actuated mirror is operated with large tilting angles at low voltage. The tilting angle of actuated mirror is expected to be high enough to satisfy the optical communication at a distance of 10 meters between the CCR and a sensor of 20 centimeters. However, the tilting angle at 0 voltage is not perfectly flat in simulated result because of the residual stress gradients in the stacked films. In the future work, these undesirable factors should be suppressed through the optimization on the material selection and the process conditions. We will assemble the actuated mirror and fabricated vertical mirror [8] into a complete CCR, and demonstrate the CCR for optical communication.

Acknowledgments

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