A High Aspect Ratio 2D Gimbaled Microscanner with Large Static Rotation

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ABSTRACT

We introduce an isolation method for SOI MEMS technologies, and demonstrate a high aspect ratio 2D gimbaled microscanner with large static rotation using the method. The proposed isolation method, termed backside island process, provides electrical isolation and mechanical coupling of SOI structures through a deep reactive ion etching the backside substrate. The fabricated 2D mirrors perform large static optical deflection from –20.3° to 15.6° by outer gimbal and from 0° to –11.9° by inner mirror.

INTRODUCTION

Silicon-on-insulator (SOI) micromirrors provide attractive features such as a flat, reflective, and robust device layer, an etch stop, CMOS compatibility, and simple fabrication for MOEMS applications [1]. A SOI staggered mirror has been demonstrated that performs well for both static and dynamic application [2]. However, it is limited to 1 degree of freedom (DoF) unidirectional rotation due to the electrically coupled lower combfingers. We have recently demonstrated independently and linearly controllable vertical combdrives for static low voltage vertical microlens actuation [3], and for 1D rotating mirror [4]. Its advantages include large displacement and bi-directional actuation. Our goal was to expend these advantages to 2DoF application.

A gimbaled structure is the most common and effective way of implementing 2DoF rotation. A Hybrid 2DoF mirror has been demonstrated by gap closing actuation, which requires additional bonding and linearization [5]. To implement 2DoF gimbaled micromirror without cross talk between driving voltages, electrical isolation and mechanical coupling are necessary. Backfilling an isolation trench with additional deposition layer followed by chemical mechanical polishing (CMP) has been used to achieve the electrically isolated mechanical coupling [6]. However, the additional deposition and CMP steps debase the advantage of using SOI.

In this paper, we present a SOI-based 2DoF gimbaled micromirror with large static rotation based on backside island isolation process. The proposed isolation method not only eliminates the need for backfilling and linearization but also enables SOI gimbaled structures.

DESIGN AND FABRICATION

The 2D gimbaled mirror is designed using 5 different silicon beams with different thickness. The cross section of the required beams is shown in Fig. 1. The design (Fig. 1a) utilizes a two-axis gimbal, where the inner mirror is electrically isolated from the outer gimbal whereas they are mechanically coupled. The isolated coupling is done by a timed-etched backside Si island below the gimbal structure, as shown in dashed rectangle of Fig.1b. This island, together with isolated comb banks, allow both upward and downward actuation of outer gimbal with five different voltages (V1-V5).

The backside island fabrication process is shown in Fig. 2. The fabrication process for vertical comb drive can be found in [3]. The thin backside island is formed by two-step deep reactive ion etching (DRIE) from the backside. (1) Masks are patterned on oxide and thick
photoresist layer; (2) timed DRIE from the back sets the thickness of island and the remained island mask is cleaned by RIE; (3) blank DRIE from the back transfer the step height of island until buried oxide is exposed and the buried oxide is cleaned by RIE; (4) The device structure is defined from the font using DRIE. Lateral shrinkage which is depending on the substrate thickness and recipe of DRIE should be considered in design due to the blank etching in (3). The buried oxide under the island work as insulated isolated connector for the top device structure.

RESULTS

SEMs of the fabricated device are shown in Fig. 3. The dashed box in Fig. 3a is where the island is attached to the bottom of the outer gimbal. Fig. 3b is a photo of the backside island taken from the back. Vertical comb bank with a torsion spring is shown in Fig. 3c.

The demonstrated static optical deflection from gimbal rotation (tipping) from $-20.3^\circ$ to $0^\circ$ at $<100$V on pads V1&V2, and from $0^\circ$ to $15.6^\circ$ for $<100$V on pads V3&V4. Inner axis (tilting) from $0^\circ$ to $-11.9^\circ$ was measured for $<100$V on pad V5. Pistoning up was performed by actuating V1&V3, and pistoning down by actuating pads V2&V4, giving static pistoning from of 13µm p-to-p at $<100$V. Table 1 summarizes the preliminary result on optical deflection.

CONCLUSION

2DoF microscanner with large static deflection is demonstrated by combination of vertical comb drive and the proposed backside island isolation. Successful electrical isolation as well as mechanical coupling, which enable SOI gimbal structure without additional deposition and CMP, has been achieved. The fabricated device demonstrate large static rotation from $-20.3^\circ$ to $15.6^\circ$ by outer gimbal and from $0^\circ$ to $-11.9^\circ$ by inner mirror.

REFERENCES