Fabrication of Free-space MOEM Component by CMOS Process

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Abstract

This work presents the micro-mirror switch array for use on free-space optical interconnect platform which integrated with a digital 1×8 de-multiplexer on-chip control circuit together. The device employs electrostatic actuation for light beam directions control. The diameter of each mirror is about 50 µm and the overall chip size is around 1.8 by 1.8 mm. The professional simulation software was utilized to validate the micro-mirror design and elucidate the behavior of the micromirror before fabrication. Also described herein are the general principles of the light-beam switching method, the detailed device design, the post-CMOS fabrication process flow, the result of simulations and preliminary experimental results.

Key Words: MEMS, CMOS-MEMS, Foundry Service

1. Introduction

The development of MEMS based micro-mirror arrays for display or image processing has attracted much interest in recent years [1, 2]. Currently available standard CMOS fabrication technologies and micro-machining techniques offer the good opportunities for creating much smaller intelligent devices, based on a micro-mirror switch arrays, for optical, or communication applications. Micro-optical-electro-mechanical systems, or MOEMS, are among several promising technological approaches for developing all optical switching connection subsystems in telecom or data networks [3, 4]. The integration of micromachined components with CMOS circuitry on a single chip has already opened up a new research field with a wide variety of applications. Consequently, the proposed micro-mirror switch array architecture employed one mirror for eight possible digital switching directions by two state positions around 0 and 9 degrees of tilting on each switching path of a mirror in the matrix switch. Additionally, the micromachined mirrors can be driven by applying around 20 V to the bottom and top electrodes which are made by metal 1 and metal 4 respectively. Although the whole processes are still underway and the measurement are still being made. However, some important information about the key point of general optical components had already been obtained by WYKO interferometer system or AFM measurement system.

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2. Design of Micro-mirror Switch Array

The fabrication of micro-mirror array for short range communication or image processing applications has attracted considerable attention over recent years. Currently available CMOS fabrication technologies and novel micro-machining techniques provide an opportunity to make intelligent cross-connect switches, based on a micro-mirror arrays, for optical telecommunication applications. The built-in intelligence of the system, together with its compactness and low insertion loss, make this device very important for a number of high-speed telecommunication applications. Each micro-mirror is attached to a central supporting post, which was made by stacked metal layers and tungsten layers, allowing a 9 degree of tilting angle at positive or negative potential applied (up or down). Figure 1 depicts the whole chip layout, and Figure 2 shows the result of finite element analysis. Additionally, the behavior of the micro-mirror switch array is also described. The light beam direction can be switched by the digital combination between on-chip electric selection lines or pads. Figure 3 shows the behavior simulation of micro-mirror array.

3. Fabrication

Figure 4 depicts schematically the cross-section of a single micromirror cell after the CMOS process was completed. Maskless post-processing was required to remove TEOS silicon dioxide material around the mirror cell to release the structure. Figures 4(a) to 4(c) show the fabrication flow of the laminar-stacked micro-mirrors. Figure 4(a) shows the cross-section after the conventional CMOS foundry service. Figures 4(b) and 4(c) show that reactive ion etching and HF based etching process were applied during the post-process to release the structure.
The silicon dioxide around the mirror cell is etched first by anisotropic CF₄/O₂ reactive ion etching and then isotropically wet etched by HF based solution. The metal layers and tungsten plugs act as the main structure of the micro-mirror. No sticking phenomenon was observed during the whole process. Figure 5 displays a scanning electron micrograph (SEM) of the laminated micro-mirror structure. Figure 6 shows the microscopic picture of proposed micro-mirror array.

4. Results

The surface properties are the most important determiners of the reflective type micro-mirror for light beam steering. So this work also presents a planted micro-mirror array to improve the optical fill factor and the reflection efficiency. Figure 7 depicts such a device. However, the measurement results (Figures 8 and 9) indicate that the CMOS compatible optical device can perform as required by most reflecting type optical components, the average roughness of the surface of the mirror is around 17 or 12.58 nm. Furthermore, the relaxation response is about the range of mini-seconds and the driving voltage is around 20 V.

5. Conclusion

This study describes a CMOS-MEMS optical component which was fabricated by silicon dioxide reactive ion etching and HF based wet etching process. The fabrication process and the measurement verified the commonly used optical devices in the possibilities of mass production at low cost. SEM and microscope pictures of this CMOS-MEMS device, detailed process flows, and the
preliminary experimental results were also presented in this paper.

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