METHOD FOR MANUFACTURING MICROELECTROMECHANICAL COMBDRIVE DEVICE

FIELD OF THE INVENTION

This invention relates generally to Micro-Electro Mechanical Systems (MEMS). More particularly, this invention relates to electrostatic combdrive devices and methods for making such devices.

BACKGROUND OF THE INVENTION

Microelectromechanical Systems (MEMS), which are sometimes called micromechanical devices or micromachines, are three-dimensional objects having one or more dimensions ranging from microns to millimeters in size. MEMS have been developed with scanning mirrors, referred to as scanning micromirrors. Such scanning micromirrors can be used in a variety of applications including barcode readers, laser printers, confocal microscopes, and fiber-optic network components such as optical switch arrays. The devices are generally fabricated utilizing semiconductor processing techniques, such as lithographic technologies. Electrostatic combdrive actuators have been developed to actuate such scanning micromirrors. Unfortunately, the combdrive actuator portion of a micromirror device can take up a large portion of chip space. The space taken up by the combdrive actuator can be a limiting factor in the number of micromirror devices that can be placed on a chip. Packing the micromirror devices closer together is desirable, e.g., in optical switch arrays, because it reduces optical path length and allows for smaller mirror design. The current state of the art of combdrive actuators is described, for example, in U.S. patent application Ser. No. 09/584,835 entitled "Staggered Torsional Electrostatic Combdrive and Method of Forming Same" to Robert A. Conant and Jocelyn T. Nee, Kam-Yin Lau and Richard S. Muller, which was filed May 31, 2001.

FIG. **1** illustrates a Staggered Torsional Electrostatic Combdrive (STEC) **20** of the prior art. The STEC **20** includes a stationary combteeth assembly **22** and a moving combteeth assembly **30**. The stationary combteeth assembly has individual combteeth **24** formed on a spine **26**. The moving combteeth assembly **30** includes individual combteeth **32** linked by a spine **34**. The moving combteeth assembly **30** also includes a mirror or paddle **40** with associated torsional hinges **42**. In a resting state a moving combteeth assembly **30** is positioned entirely above the stationary combteeth assembly **22** as shown in FIG. **1**. A typical prior art process flow involves creating the moving combteeth assembly **30** and the mirror **40** out of the same device layer of a silicon-on-insulator (SOI) wafer.

FIG. **2** illustrates the STEC system **20** in an activated state. This state is achieved by applying a voltage between the moving combteeth assembly **30** and the stationary combteeth assembly **22**. In this state, the individual combteeth of the two assemblies interdigitate. The applied voltage attracts the moving combteeth assembly **30** to the fixed combteeth assembly **22**, thus exerting torque on the torsional hinges **42**, forcing the mirror **40** to tilt. The torsional hinges **42**, which are anchored, provide restoring torque when the voltage is removed. Note that the combteeth assemblies **22**, **30** take up space that might otherwise be used for additional mirrors. This restricts the density to which devices such as the STEC **20** can be packed. The packing density might be improved somewhat by forming the combteeth **32** at the edges of the

mirror **40**, but the combteeth **32** would still take up space and restrict the packing density of the mirrors.

Thus, there is a need in the art, for a combdrive device that can be densely packed and a method for fabricating it.

BRIEF DESCRIPTION OF THE DRAWINGS

The teachings of the present invention can be readily understood by considering the following detailed description in conjunction with the accompanying drawings, in which:

FIGS. **1**–**2** are isometric diagrams of a Staggered Torsional Electrostatic Combdrive (STEC) according to the prior art;

FIGS. **3A**–**3D** depict different views of a combdrive device according to an embodiment of the invention;

FIGS. **4A**–**4B** depict side elevation views of alternative combdrive devices according to an embodiment of the invention; and

FIGS. **5A**–**5L** depict cross-sectional schematic diagrams illustrating the fabrication of a combdrive device according to an embodiment of the present invention.

DESCRIPTION OF THE SPECIFIC EMBODIMENTS

Although the following detailed description contains many specific details for the purposes of illustration, anyone of ordinary skill in the art will appreciate that many variations and alterations to the following details are within the scope of the invention. Accordingly, the embodiments of the invention described below are set forth without any loss of generality to, and without imposing limitations upon, the claimed invention. In the drawings, like numbers refer to like elements throughout.

FIGS. **3A**–**3D** depict different views of a microelectromechanical combdrive device **300** according to an embodiment of the present invention. The device **300** generally includes a movable element **302** having a set **310** of one or more comb teeth **312** that extend from a major surface of the moveable element **302**. As used herein, the term "major surface" generally refers to an exposed surface having a relatively large surface area compared to other surfaces of the moveable element **302**. Depending on the shape of the moveable element **302**, there may be more than one major surface. By way of example, in the case of the substantially rectangular moveable element shown in FIGS. **3A**–**3D**, the top and bottom surfaces of the rectangle would be regarded as major surfaces. In the example shown in FIGS. **3A**–**3D**, the comb teeth **312** extend from the bottom surface of the moveable element **302**. The moveable element **302** may include a light-deflecting portion **307**. The light deflecting portion **307** may include may include a mirror, such as a simple plane reflecting (or partially reflecting) surface, or a curved reflecting (or partially reflecting) surface. Alternatively, the light-deflecting portion **307** may include one or more prismatic reflectors, refractive elements, prisms, lenses, diffractive elements, e.g., fresnel lenses, a dichroic coated surfaces for wavelength specific and bandpass selectivity, or some combination of these.

The moveable element **302** may be formed from a first device layer **303** of a multi-layered substrate such as a silicon-on-insulator (SOI) wafer. The moveable element **302** may be moveably connected to a portion of the first device layer **303** by a flexure **304**. The flexure **304** may be a torsional flexure with a suitable cross-section including a rectangular, I-shaped, or T-shaped cross-section, a cantile-