Use of Continuous Hinges and Microrivets to Facilitate the Assembly of Three-Dimensional Polysilicon Microelectromechanical Systems (MEMS) Structures

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The seamless integration of conventional microelectronics with three-dimensional, microdynamic, mechanical components is one of the prominent goals of microelectromechanical systems (MEMS) technology. Conventional microelectronic integrated circuit (IC) processing is predominantly a two-dimensional fabrication technique. On the other hand, many MEMS microsensor and microactuator applications require three-dimensional components. Since MEMS technology is an extension of IC processing, the primary challenge is to realize mechanical components with physically large and high-resolution features in all three dimensions. Most of the common IC fabrication processes either sacrifice planar resolution for depth, or compromise vertical feature size to achieve high planar resolution.

Conventional surface micromachining manifests high planar resolution, low vertical resolution, and limited vertical range (typically less than 5 µm). These characteristics are indicative of an excellent planar (two-dimensional) process, but would otherwise imply limited utility for three-dimensional MEMS applications. Nevertheless, the authors have adapted this popular MEMS fabrication technology to produce robust, three-dimensional structures whose components are fabricated as planar entities. The planar entities are then rotated out of the plane of the silicon substrate on integrally fabricated hinges, whereby they are assembled and joined using arrays of open windows and microrivets. The resulting three-dimensional structures not only manifest IC quality resolution in both the planar and vertical dimensions, but now the vertical feature sizes that are realizable span from 1 µm to nearly a millimeter.

The fabrication process for producing three-dimensional structures from microhinged and latachable polysilicon panels was developed using the popular Multi-User Microelectromechanical Systems (MEMS) Process (MUMPs) foundry and material system.

Figure 1 depicts two, three-dimensional MEMS structure designs that incorporate the continuous microhinge and the matrices of etch holes and dimples in the elevatable panels. The lower elevatable panels in Figure 1(a) and (d) are terminated with the laminated Poly 1 and Poly 2 window array structure depicted in Figure 1(b) that also traps Oxide 2 reinforcement ribs. The opening of each window is 25 µm x 20 µm. The upper elevatable panels in Figure 1(a) and (d) are terminated with the window latching/locking elements. Figure 2 depicts the assembled versions of the MEMS structures depicted in Figure 1.

It is reasonable to project that the continuous microhinge concept could also be adapted to elements not attached to the substrate, thus affording an even higher degree of freedom for realizing more complex three-dimensional MEMS structures.

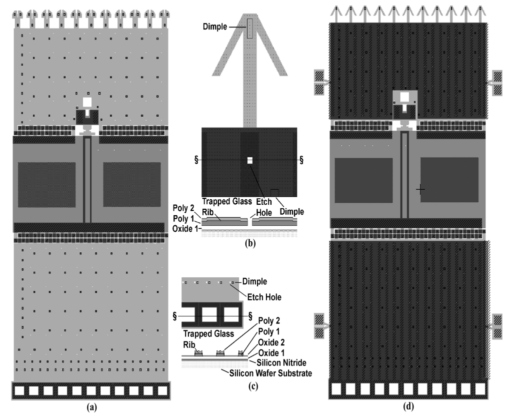
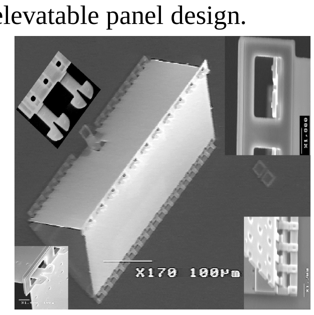
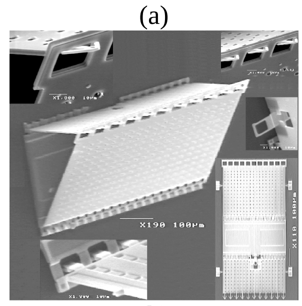


Figure 1. MEMS structures incorporating the continuous microhinge. (a) Elevatable microhinge panels fabricated from a single Poly 1 layer. The upper panel is terminated with the microrivet design. The lower panel is terminated with the laminated window array. (b) Detail of the arrowhead locking element and the laminated Poly 1 and Poly 2 elevatable panel. (c) Detail view of the window design. (d) Three-dimensional MEMS structure whose elevatable microhinge panels are fabricated with the laminated Poly 1 and Poly 2 elevatable panel design.



(a)



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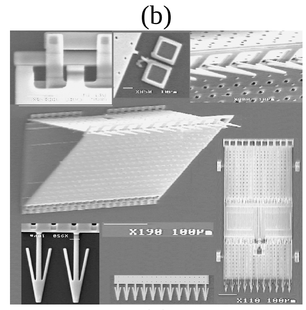

(c)