MEMS Reliability Alliance
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DIMPLED HINGE DESIGN AND ANALYSIS

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The MEMS Reliability Alliance is composed of three core institutions:

(1) MEMScaP S.A., a MEMS software company who provides the MEMS-Pro design software.
(2) Cronos Integrated Microsystems, a wholly-owned subsidiary of JDS Uniphase. Cronos provides a polysilicon surface micromachining process (MUMPs^{TM}) to the international MEMS community
(3) Jet Propulsion Laboratory, which provides the MEMS test structure design, release etching, testing, and characterization.

Dimpled hinges were designed at JPL using MEMS-Pro and fabricated using the MUMPs^{TM} process at Cronos (see Figure 6). The top-view layout and side-view cross section are shown in Figures 1 and 2. These are essentially modified substrate hinges, consisting of a poly1 flap and hinge-pin secured to the substrate using a poly2 staple. A dimple is patterned through the hinge as shown in Figure 1. It overlaps the poly2 staple by 1μm on either side.

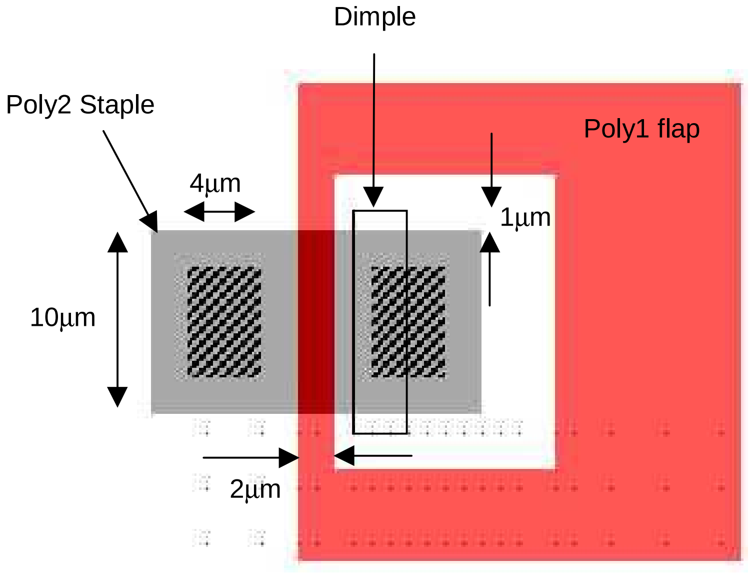

Figure 1. Top view of the hinge layout drawn using MEMS-Pro software. Dimple patterned through the right side of the hinge overlaps the poly2 staple by 1μm on either side.

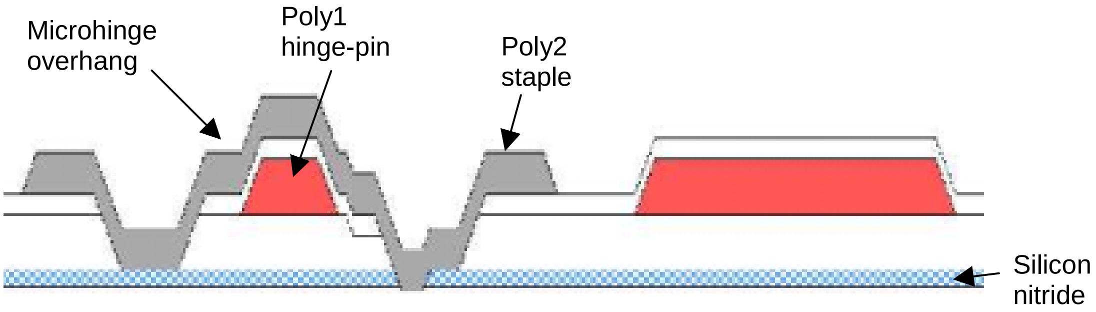

Figure 2. Cross-section through the hinge, as simulated using MEMS-Pro software. Dimple patterned through the right side of the staple lowers that part of the poly2 overhang. Also shown in this cross section are both sacrificial oxide layers (oxide 1 and oxide 2) and the silicon nitride layer that covers the whole substrate for electrical isolation.

The dimple patterned through the staple lowers the poly2 overhang as shown in Figure 2. After release etching, the sacrificial oxide layers are etched away and the poly1 plate and hinge pin are free to rotate. The dimple is mainly used to prevent the poly1 hinge pin from getting pegged under the poly2 staple overhang during the poly1 plate rotation. Pegging of the poly1 hinge pin can result in structures locked at an angle to the substrate. Further rotation will break the hinge pin and cause device failure.

SEM photos of the actual hinges (after release etching) are shown below. Important features are noted in the figure captions. Most notably, the dimple is **misaligned** – it is not symmetric about the staple but shifted to one side. This shift will not affect hinge performance, as the dimple will still serve its function. In fact, the dimples increased yield of successfully functioning parts. Poly1 plates that were rotated about these staples could successfully be rotated forwards 180° and back to the original position without the hinge pins getting pegged under the staple. Hinges without dimples run the risk of pegging the pin, as evidenced in Figure 5.

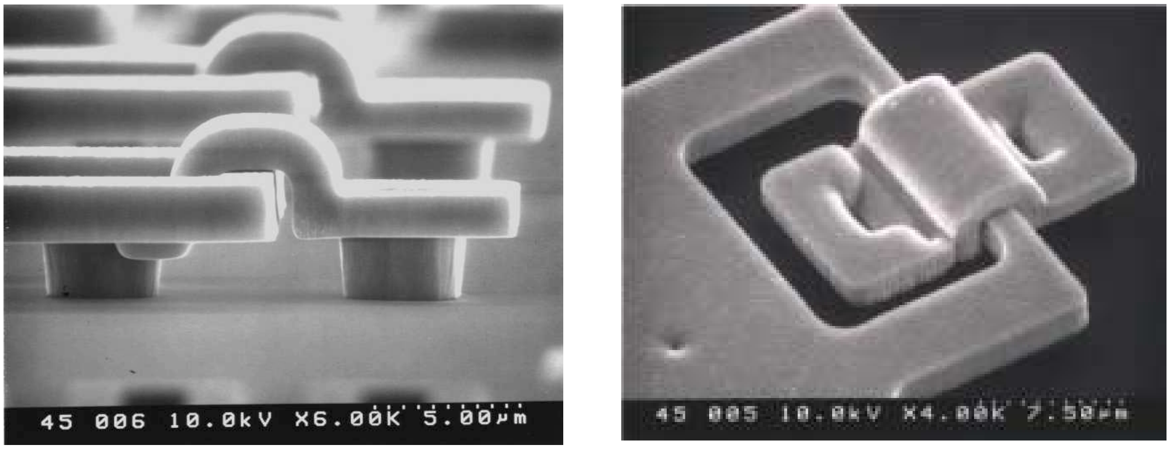

Figure 3. Left: Side view of the hinge before poly1 plate rotation, showing dimple patterned through the left side (ridge clearly visible). Right: Perspective view of the same hinge, showing misalignment of the dimple (shifted upwards).

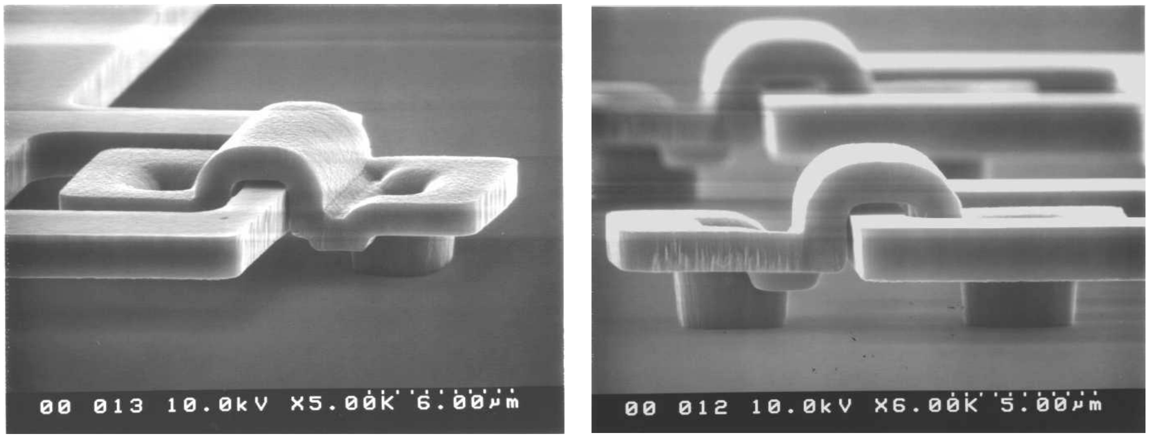

Figure 4. Side view of the hinge after poly1 plate has been rotated 180°. Left: view of the side of the hinge showing the ridge created by the dimple clearly. Right: view of the side of the hinge where the poly2 was not fully etched in the dimple, indicating dimple misalignment. Ideally, the ridge should be clearly visible on both sides.

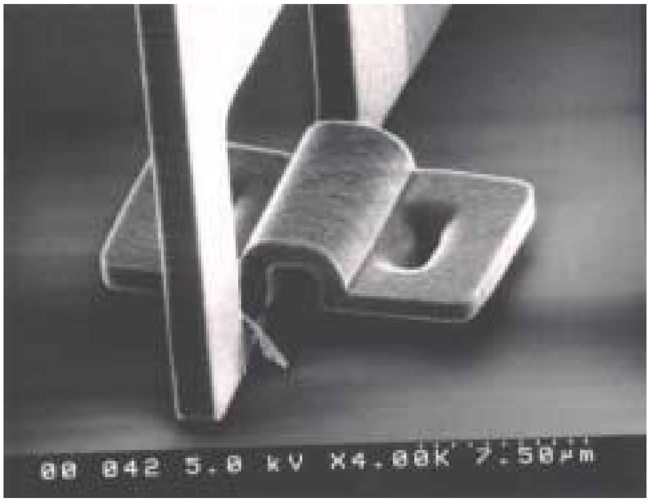

Figure 5. SEM photo of a hinge without the dimple patterned through it. While rotating the poly1 plate, the hinge pin got pegged under the poly2 staple. Any further rotation will break the pin. Also, rotation of the poly1 plate is now irreversible.

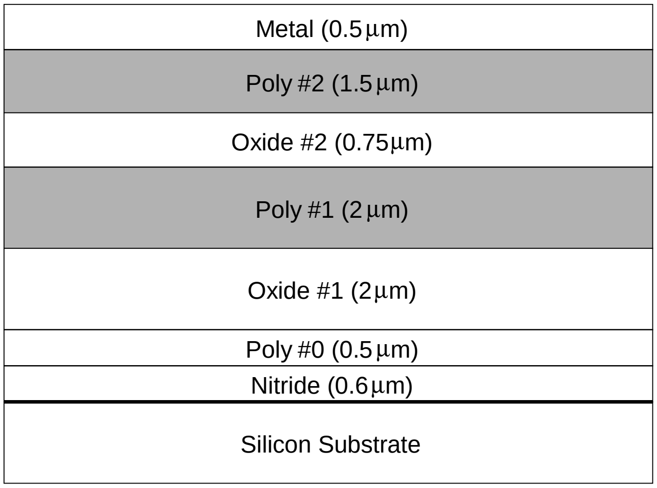

Figure 6. MUMPs™ layer stack. Poly1 and poly2 are structural polysilicon layers, while the oxides are sacrificial layers in that they do not appear in the final structure. Poly0 is used as a ground plane and the nitride is used for electric isolation. Metal layer on top (gold) is for optional contact metalization.

Conclusions

- Polysilicon hinges were designed with the dimple layer patterned through part of the hinge.

- Dimple layer in the MUMPs™ process is misaligned -- is it not symmetric about the staple but shifted to one side.

- This shift did not affect hinge performance, as the dimple still prevented the poly1 hinge pin from being pegged under the poly2 staple. Thus, yield of successful parts was increased.