Micro Joints, Actuators, Grippers, and Mechanisms

Ted Hubbard, Marek R. Kujath, Heiko Fettig

Mechanical Engineering, Dalhousie University, Halifax, Canada
ted.hubbard@dal.ca, marek.kujath@dal.ca, fettig@micron.me.dal.ca

1. Introduction

This paper describes micro joints, actuators, mechanisms, and manipulators. The designed mechanisms are of a sub-millimeter scale and their intended application is to manipulate microorganisms such as bacteria and yeast cells or to reorient and direct laser light beams. Micro-electro-mechanical Systems (MEMS) are small devices manufactured on a wafer of silicon using processes similar to micro-electronic fabrication. Micro machining is an interdisciplinary field combining electrical and mechanical engineering, physics, and chemistry. Surface micro machining uses structural and sacrificial layers to form thin, high resolution structures on the surface of the wafer with overall dimensions in the range of 10-1000 microns and the feature sizes in 1-10 microns. The sacrificial layers are removed in the micro machining process by etching; this way the structural parts are freed from the wafer. In the reported research, MUMPs micro machining technology was used. The minimum cross-sectional size of a micro beam was constrained by the MUMPs design rules to approximately 2 x 2 microns. The structural material of the micro members is polysilicon.

2. Flexure Joints

On the micro scale, high sliding friction and high wear rates dramatically limit the use of members involving surface contact. In their place, compliant mechanisms with flexure joints can be used. Figure 1 shows examples of micro-joints integrated into a flexure-mass system for stiffness measurements via resonance testing. The micro devices are designed to be self supporting with anchors at the left ends in Figure 1. The flexures are formed symmetrically and are named after their resemblance to the alphabet letters: I, S, H, U, X, V. The lowest frequencies of vibration modes start at thousands of oscillations per second and can easily reach the ultrasound range (above 20 kHz) [1]. Flexures have been used at the macro and micro scale [2].

3. Actuators

Figure 2 shows thermal actuators; they are often used in batteries of several units (see Figure 3). The motor consists of two parallel cantilever beams jointed at the far end. The beams form an electrical loop. Because the beams have different widths, the thinner beam has larger electrical resistance and therefore it heats up and expands more than the thicker beam. The resulting expansion differential between the two cantilevers causes the two beam assembly to bend.

4. Grippers

Figure 3 shows a fabrication layout for a mechanisms with two grippers designed to capture yeast cells and to, possibly, measure cell separation forces.

5. Manipulators

A spatial manipulator (see Figure 4) was developed that would be lifted and unfolded from the flat fabrication position to a spatial parallel manipulator. The 3 DOF manipulator was designed to provide out-of-plane heaving plus pitch and roll with respect to a horizontal plane. Figure 5 shows a photograph of a final stage of testing by an external probe of the manipulator from Figure 4. It illustrates how brittle the polysilicon structures are but still they have enough elasticity, if made slender, to facilitate flexures.

6. Conclusion

The paper described development of micro-components and mechanisms for planar and spatial operation.

7. References

[1] H. Fettig, T. Hubbard, and M. R. Kujath: "Simulation and Modeling of Compliant Micro-Mechanisms", , 2000 SEM IX Int'l Congress, *Microscale Systems Symposium*, 8 June 2000, Orlando, FL, pp. 12-18.

[2] U. D. Larson, O. Sigmund, and S. Bouwstra: "Design and fabrication of compliant micromechanisms and structures with negative Poisson's ratio", *J. of MEMS*, 6(2), pp. 99-106, June 1997.

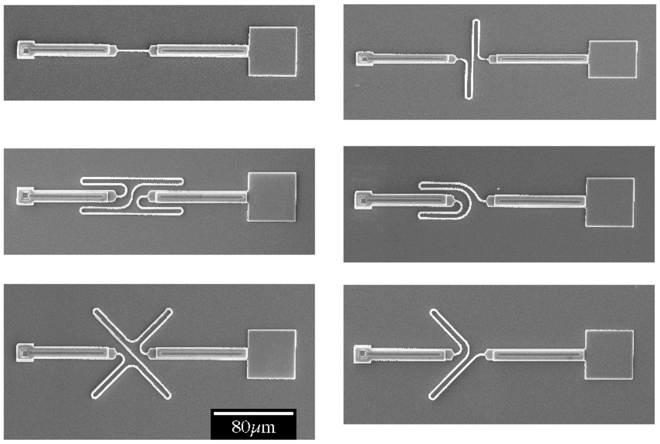

Figure 1. Flexure-mass set-ups for resonance testing.

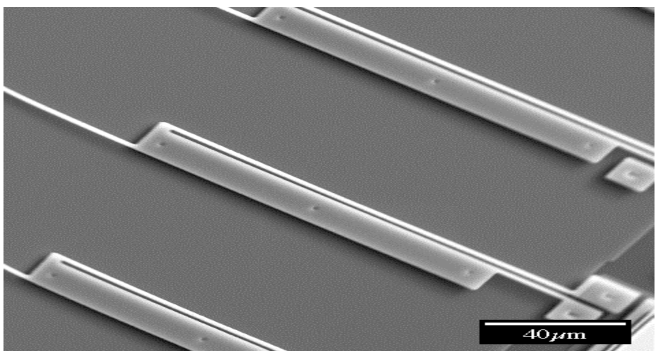

Figure 2. Polysilicon thermal actuators.

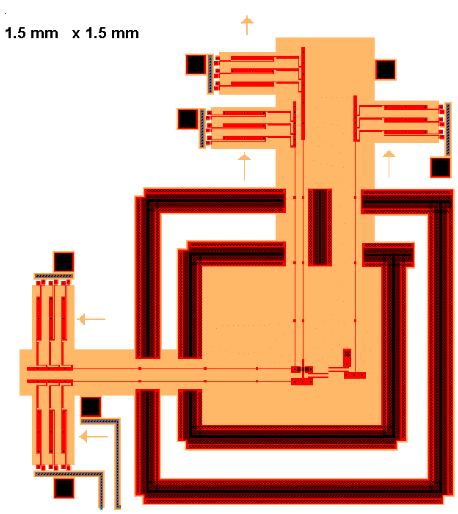

Figure 3. Micro-manipulator with grippers for yeast cell separation.

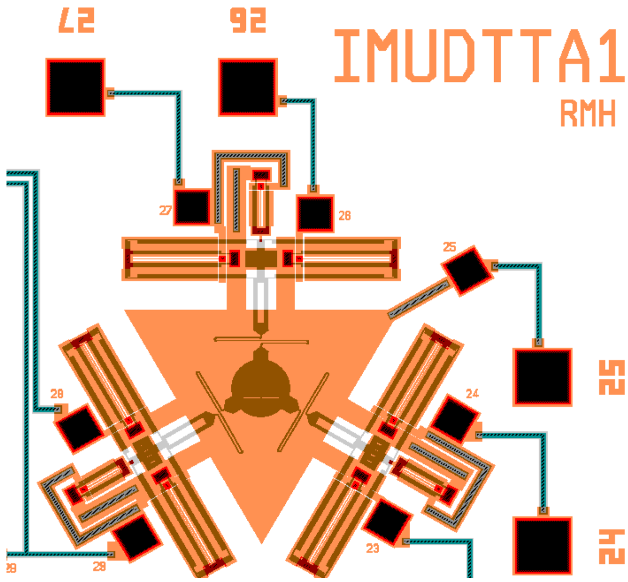

Figure 4. Fabrication layout of a spatial parallel manipulator.

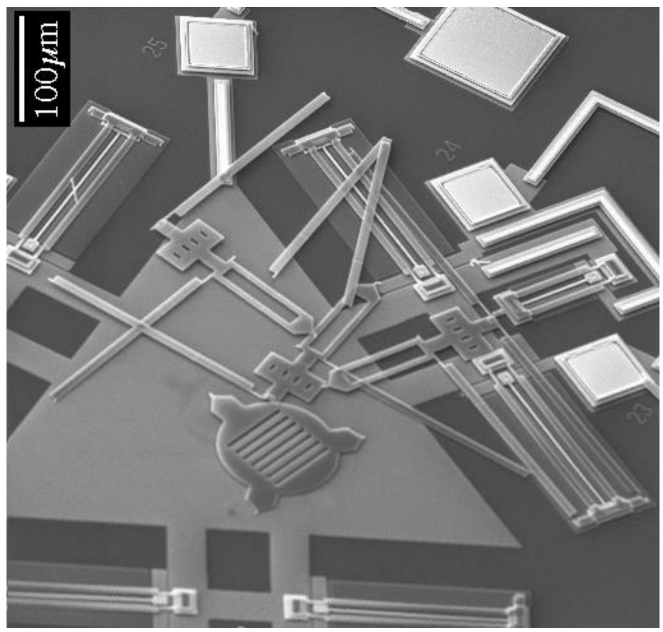

Figure 5. Test "results" of the manipulator of Figure 4.