Large Stroke Actuators for Adaptive Optics

Bautista Fernández and Joel. A. Kubby
Department of Electrical Engineering
University of California at Santa Cruz

Abstract

A 3-dimensional MEMS fabrication process to prototype large stroke (>10 µm) actuators as required for use in future adaptive optics systems in astronomy and vision science is presented. The Electrochemical Fabrication (EFAB^{TM}) process creates metal micro-structures by electroplating multiple, independently patterned layers. The process has the design freedom of rapid prototyping where multiple patterned layers are stacked to build structures with virtually any desired geometry, but in contrast has much greater precision, the capability for batch fabrication and provides parts in engineering materials such as nickel. The design freedom enabled by this process has been used to make both parallel plate and comb drive actuator designs that can have large vertical heights of up to 1 mm. As the thickness of the sacrificial layers used to release the actuator is specified by the designer, rather than by constraints of the fabrication process, the design of large-stroke actuators is straightforward and does not require any new process development.

Objective

- Create parallel plate and comb drive actuator designs
- Obtain a Pull-in Voltage <= 200V
- Obtain a large-stroke ~ 10µm

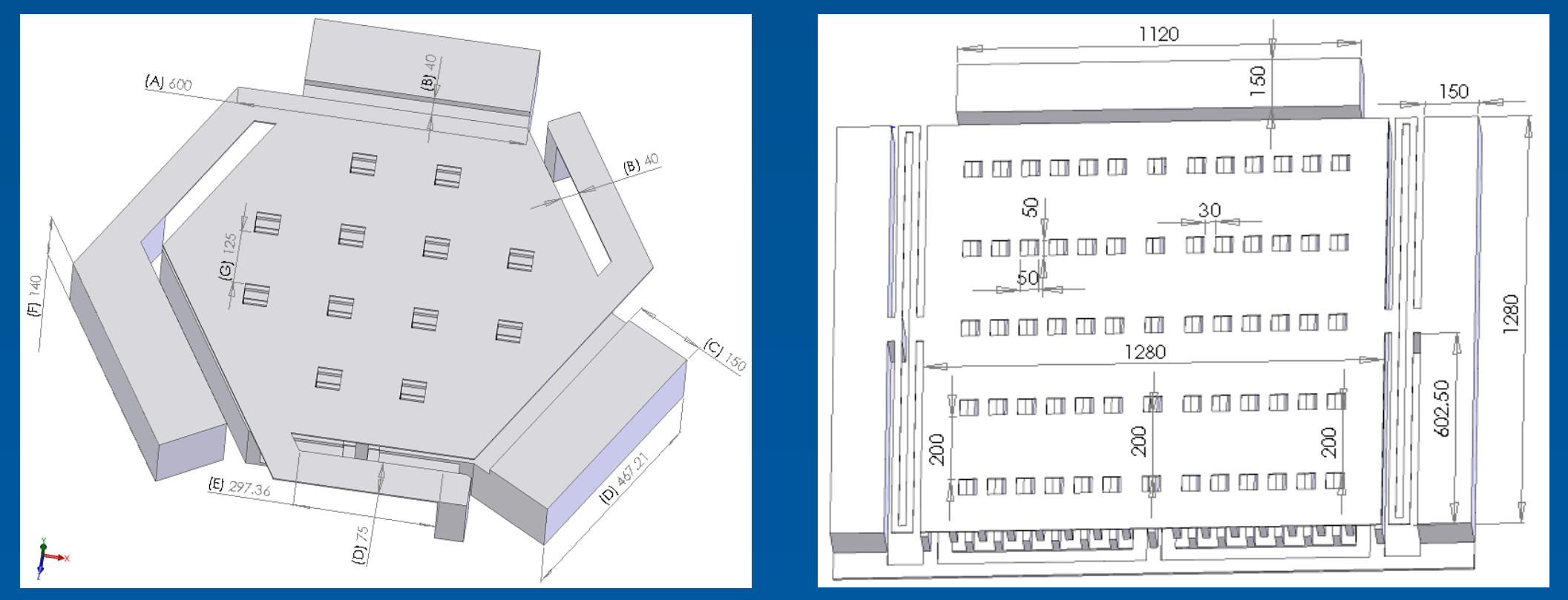

Figure 1 & 2: Top view of parallel plate and comb drive actuator designs, respectively. Dimensions shown are in µm.

Requirements

Large-Stroke	(10µm)
Low-Voltage	(<200V)
Large-bandwidth	(10KHz)
Linear Response	

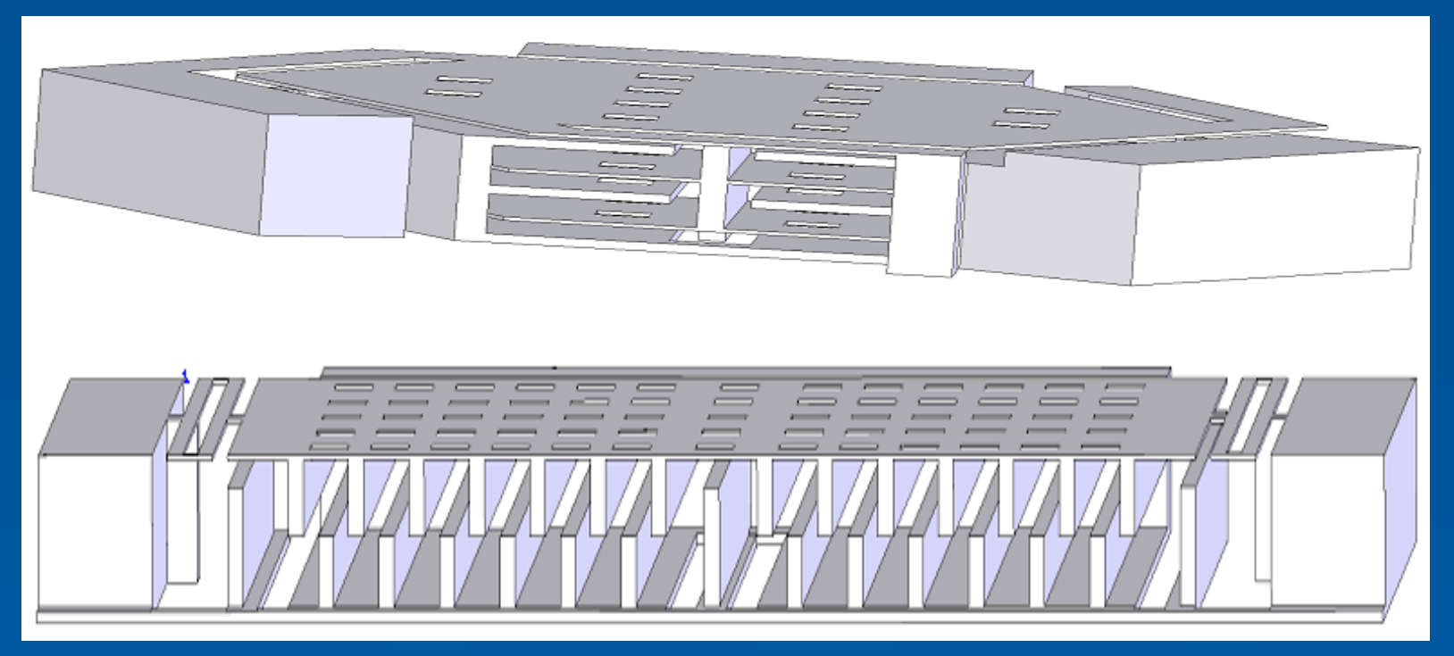

Figure 3: Front view of parallel plate and comb drive actuator designs.

Sample Cross-Section

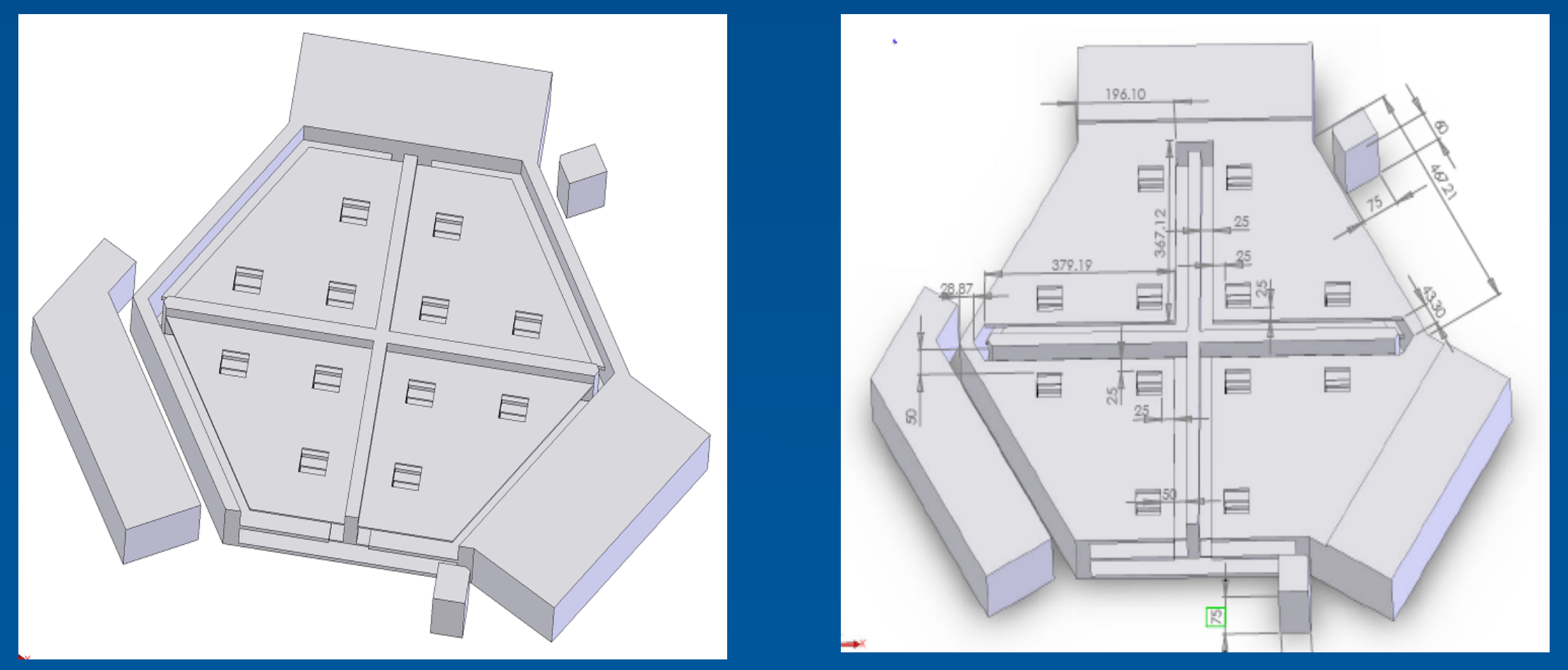

Figure 4 & 5: Top view of parallel plate cross sections. Dimensions shown are in µm.

EFAB Process

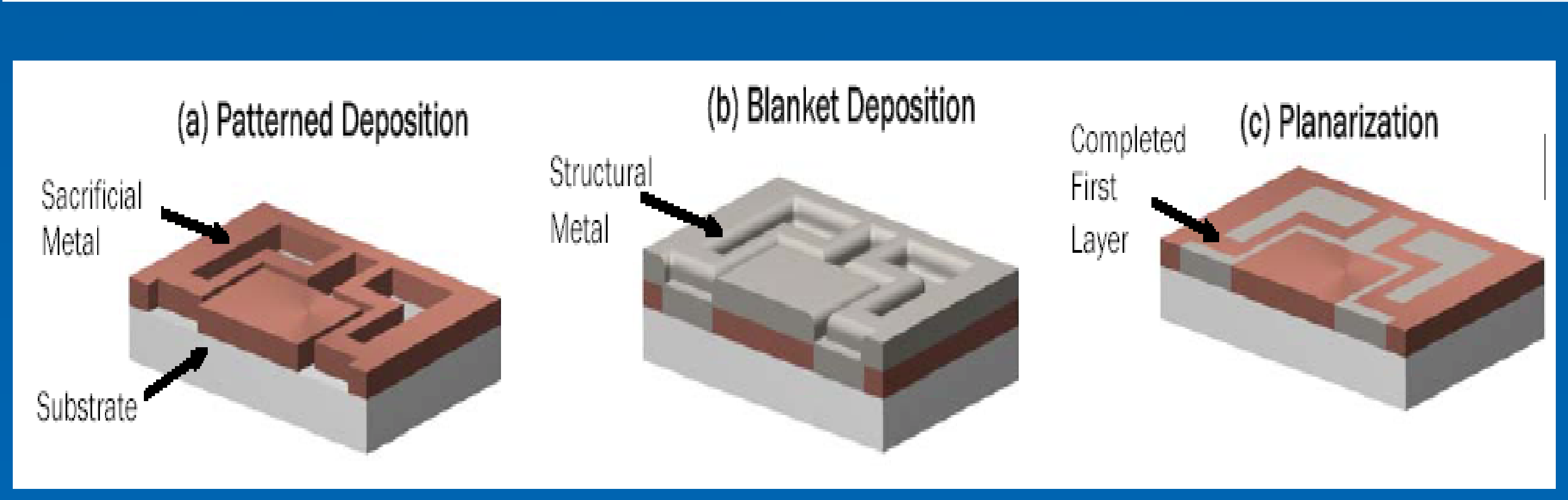

Figure 6: EFAB Process

1. A patterned copper sacrificial layer is electrodeposited on a 1.0mm thick alumina substrate.
2. A nickel layer is electrodeposited to fill the gaps left after step one.
3. Planarization of step two.

EFAB Manufactured Actuators

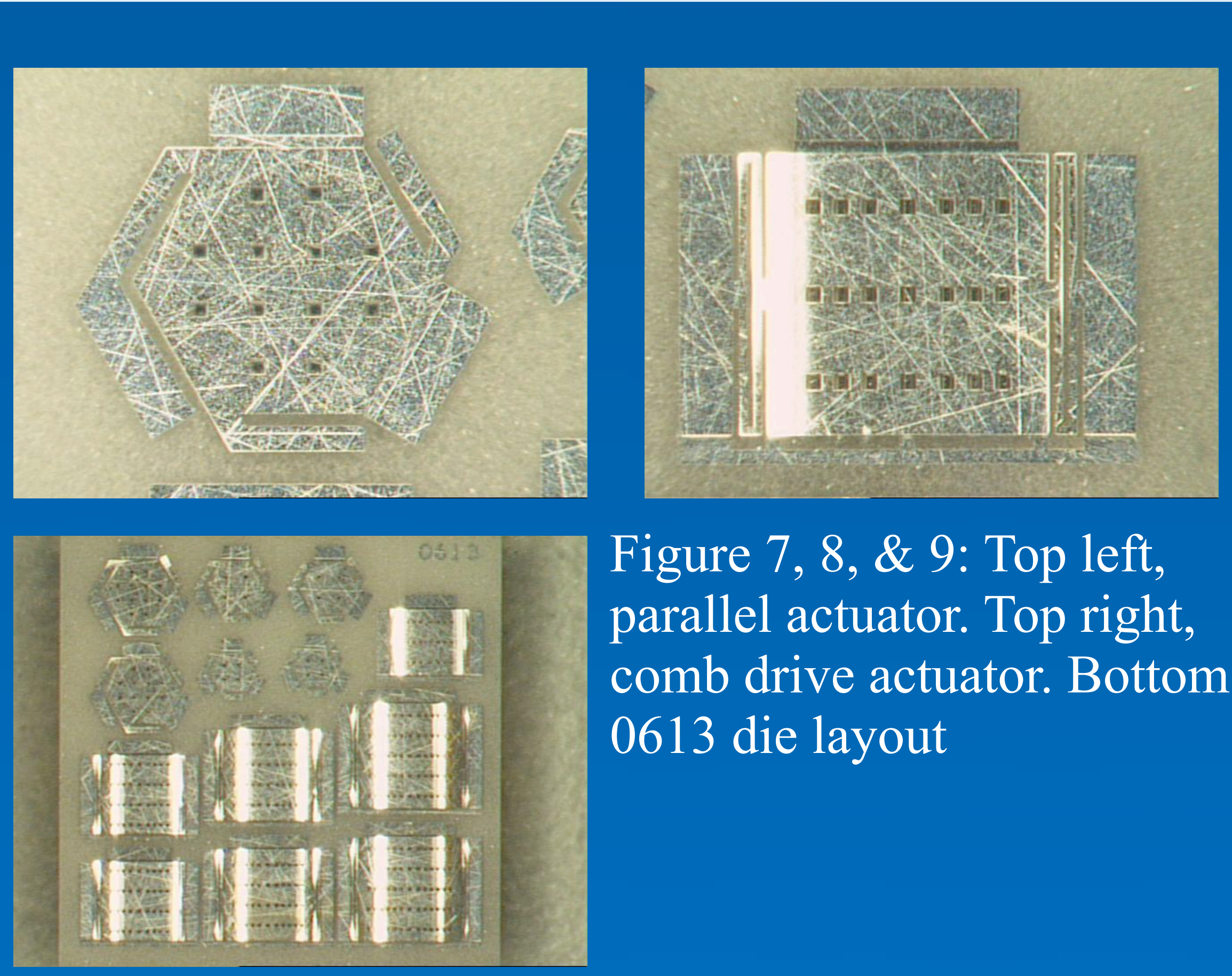

Figure 7, 8, & 9: Top left, parallel actuator. Top right, comb drive actuator. Bottom, 0613 die layout

Expected Results

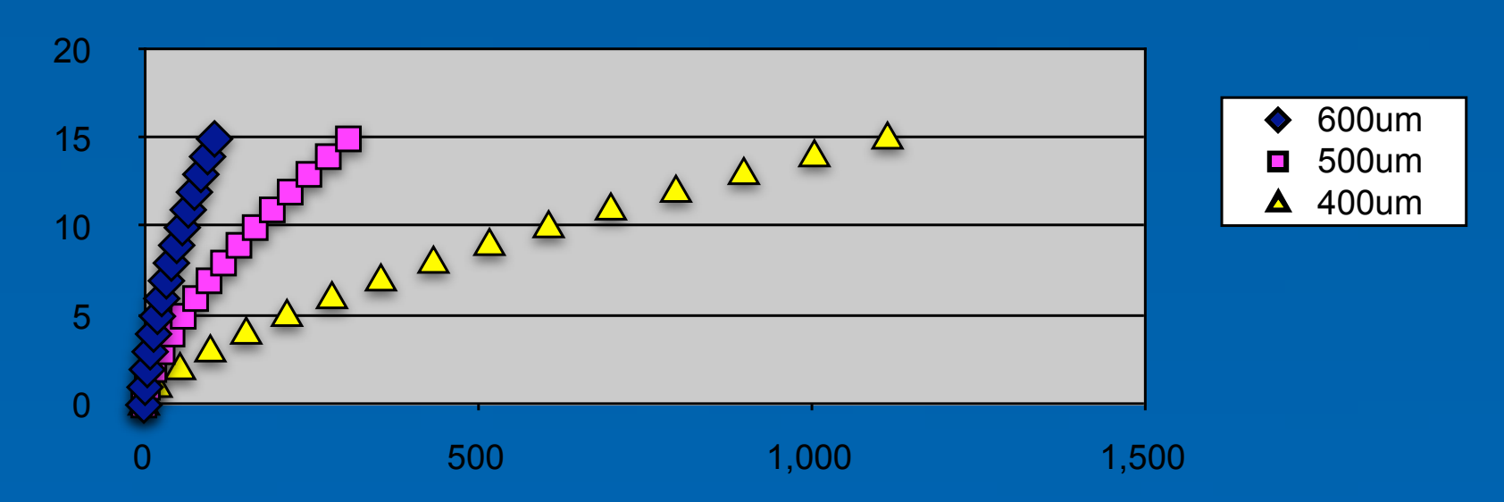

Figure 10: Displacement vs. Voltage for parallel plate actuators

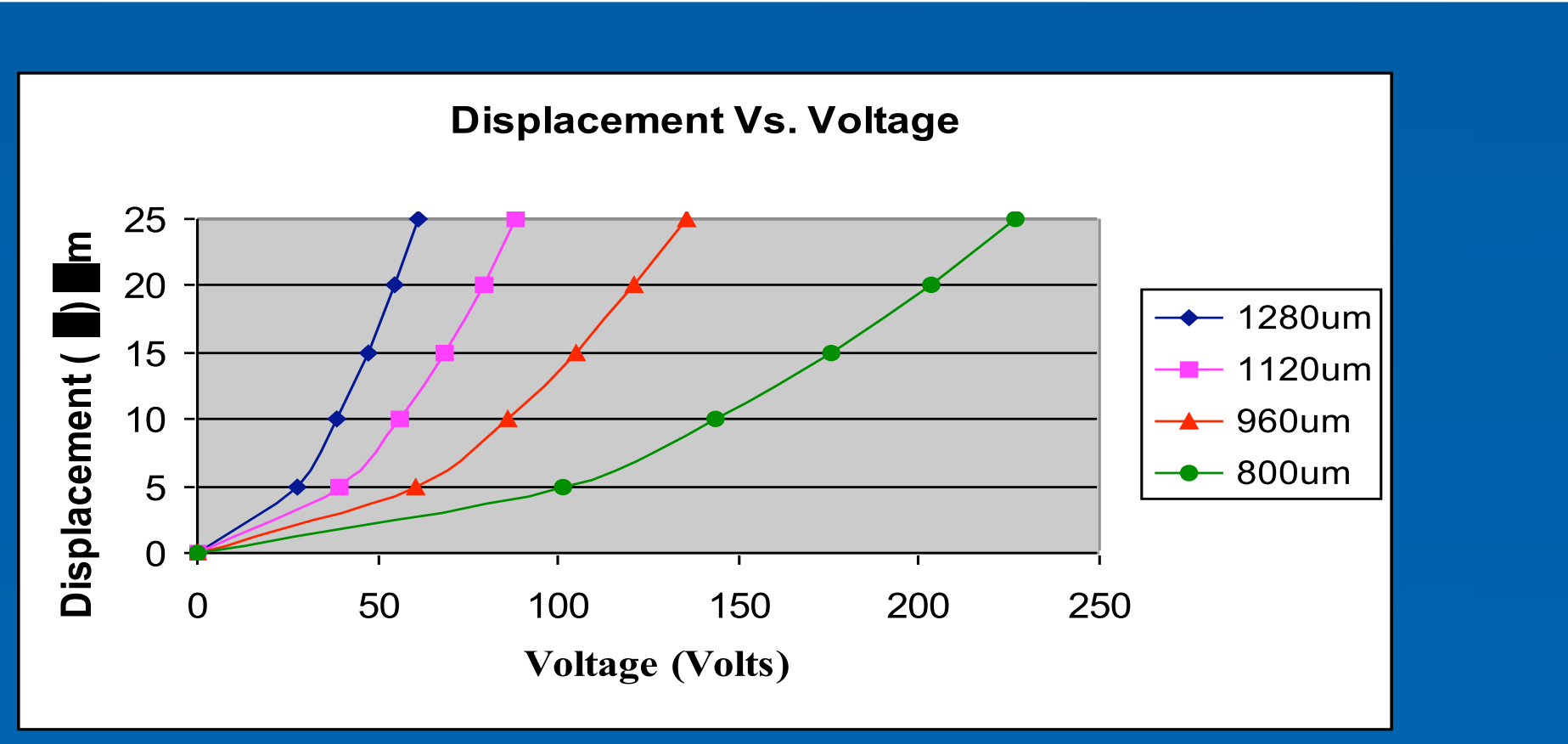

Figure 11: Displacement vs. Voltage for comb drive actuators

	600µm	500µm	400µm
K_{eff} (N/m)	104	316	1745
V_{PI} (V)	**96**	**277**	**1006**

Table 1: Pull-in voltage for parallel plate actuators

	1280µm	1120µm	960µm	800µm
K_{eff} (N/m)	2	3	6	10
V_{PI} (V)	**55**	**79**	**121**	**203**

Table 2: Pull-in voltage for comb drive actuators

0613 Die Preliminary Data

O613 Parallel Plate Actuator

Trial	V_{pi} (V)	%Error: Theoretical Calculations
1	98	2.45
2	94	1.70
3	98	2.45
4	92.1	3.80

Average: 96 ± 3 Volts

Table 3: Preliminary Pull-in voltage for parallel plate actuator.

Conclusion

We have designed and fabricated two designs for large-stroke actuators using the EFAB process. The first design is a hexagonal ganged parallel plate actuator with 4.67 µm of stroke. The second design is a rectangular comb drive actuator with 24 µm of stroke. The pull-in voltage for the hexagonal actuators is in good agreement with analytical calculations. We have measured a stroke of 28 µm for the largest comb drive actuators. Both the hexagonal parallel plate actuators and the rectangular comb drive actuators show signs of stress related deformations that are now being characterized with non-contact profilometry.

Outstanding Issues

- White-light interferometer measurements
- V_{pi} measurements

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