

### **AFAM: Articulated Four Axes Microrobot**

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## Revolutionizing micro-assembly

- □ Current micro-assembly systems
  - Large size
  - Inability to merge units
  - Limited throughput
- □ Solution AFAM
  - Small size
  - Multiple units
  - Expandable throughput
  - Maximize operating envelope





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## **Research Goals**



- Develop electrostatic actuator
  - Replace pitch control
  - Decreased footprint
  - Increased durability
  - Simplified assembly
- □ Create designs testing parameters
  - Number of fingers 10, 16
  - Length of spring 480, 1160 microns
  - Spring thickness 6, 8 microns

- □ Fabricate device
  - Manipulate DRIE recipe
  - Calculate acid bath time
  - Prevent water tension from binding rotor and stator to handling layer

New AFAM Design





## Design



### **Fabrication Process**

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## Fabrication – Attempts 1,2,3



### Attempt 1

- Default Recipe 30 minutes
- 4 seconds passivation time
- Helium Leak-Up Rate: 9.7

### Attempt 2

- Default Recipe 12 minutes
- 4 seconds passivation time
- Helium Leak-Up Rate: 15.1

### Attempt 3

- Default Recipe 11 minutes
- 4 seconds passivation time
- Helium Leak-Up Rate: 6.8



### Attempt 2



#### Attempt 1



#### Attempt 3

## Fabrication – Attempt 4

#### Process

- Lithography
  - HMDS/MCC Primer
  - 1827 Photoresist
  - 13 Second Exposure
- DRIE
  - Default Recipe <u>20 Minutes</u>
  - 9 seconds etch
  - <u>5.2</u> seconds passivate
  - Helium leak up rate: 7.2

### Release

- <u>25 minutes</u> O2 clean RIE
- 49% HF <u>10 minutes</u>



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### Results





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## Characterization



- Power Supply
- □ High Voltage Amplifier
- GIMP Measurement Tools







### Results

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- 16 Finger Curved Spring had the maximum angular displacement
- □ Repeatable angular displacement
- Possible to calculate voltage to attain desired angular displacement
- □ Parabolic Relationship confirms model  $\mathcal{E}hV^2$

$$F = \frac{cnv}{d}$$



#### 16 Finger 6 um Curved Spring Simulation ANSYS





### Conclusion

- 16 Finger 6 um with curved spring is optimal configuration from among those fabricated
- ❑ Experimental results qualitatively confirm parabolic models
- □ Fabrication process optimization included:
  - Process 10 minutes of 49% HF bath
  - 5.2 seconds passivation time DRIE running for a minimum time of 11 minutes
  - Clean photoresist with acetone bath, then oxygen clean RIE for 25 minutes

### **Future Work**

- Design and fabricate final rotary actuator for AFAM
- Design and fabricate electrical interconnects for AFAM as out of plane actuator
- Refine the assembly process to complete microrobot

# References and Acknowledgements LOUISVILLE. NEXT GEN



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WASHINGTON STATE

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## Attempt 1





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### Attempt 3



