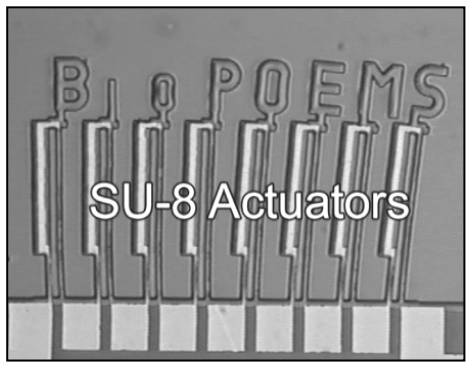
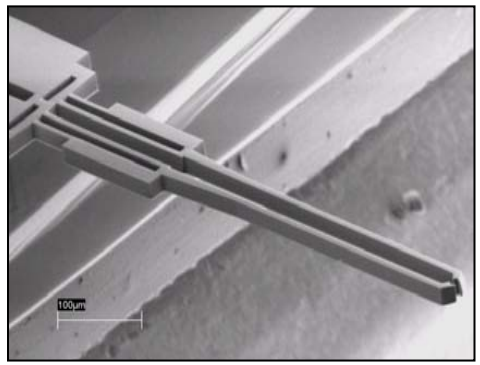
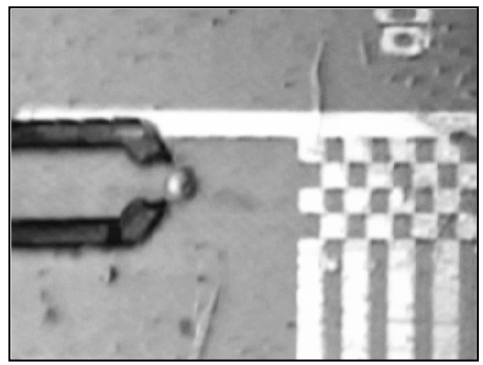
Polymer-based Microgripper for Single Cell Manipulation

Nikolas Chronis and Luke Lee



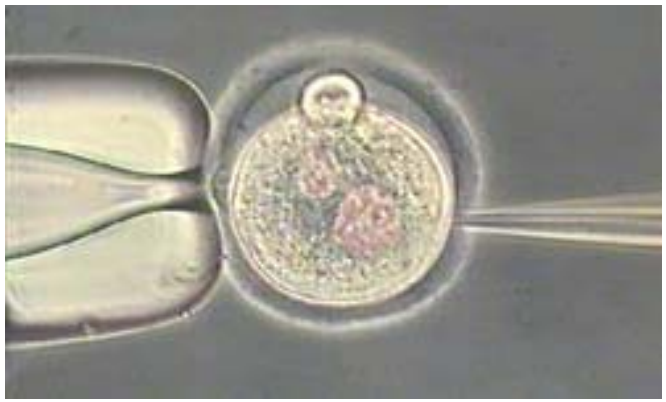




Berkeley **S**ensor and **A**ctuator **C**enter
University of **C**alifornia at **B**erkeley

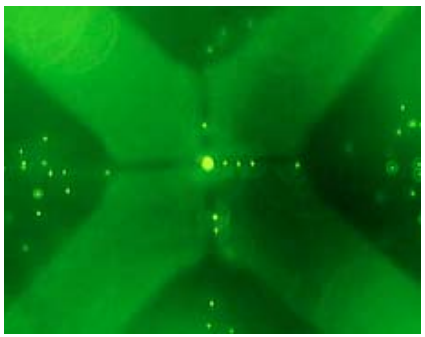
Manipulating Biological Samples

Micro Capillaries



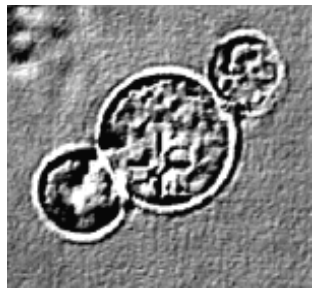
http://www.brinkmann.com

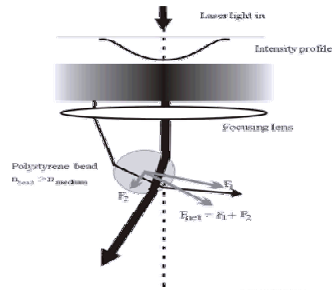
Dielectrophoretic Cages

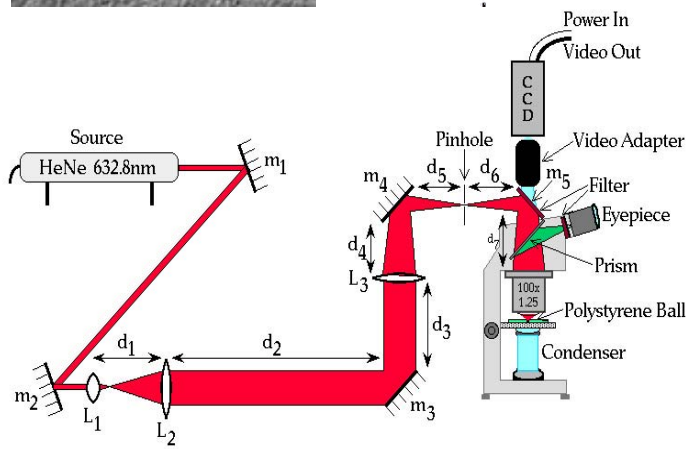


NG Green et al.,
Appl. Phys. 33 (2000)

Optical Tweezers







http://atomsun.harvard.edu/tweezer
http://www.intracel.co.uk

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MEMS Microgrippers in Liquids

Actuation Mechanism	Environment		Comments - Limiting Factor
	Air	Liquid	
Electrostatic	√	X	• Non-activated in electrolytic media
Electrothermal (Si-based)	√	X	• High temperatures (T≈ 400-600°C)
Piezoelectric	√	X	• Electrolysis (due to high voltages) • Small displacement
Ionic Diffusion	X	√	• Restricted motion (out of plane) • Questionable biocompatibility

Electrothermal (SU-8 based)	√	√	Single Cell Manipulation in Solution

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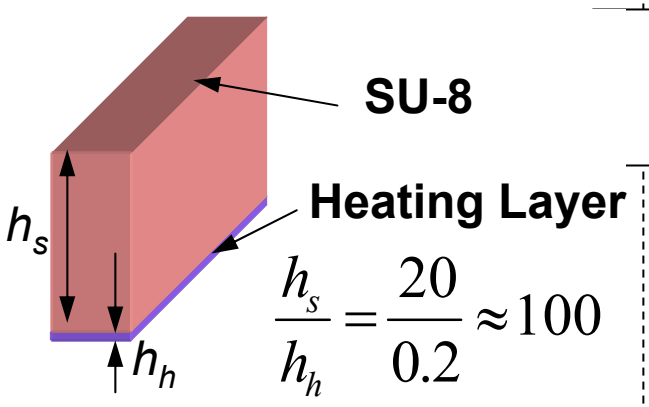
Electrothermal SU-8 Actuators

SU-8 ACTUATORS

Structural Material:
SU-8

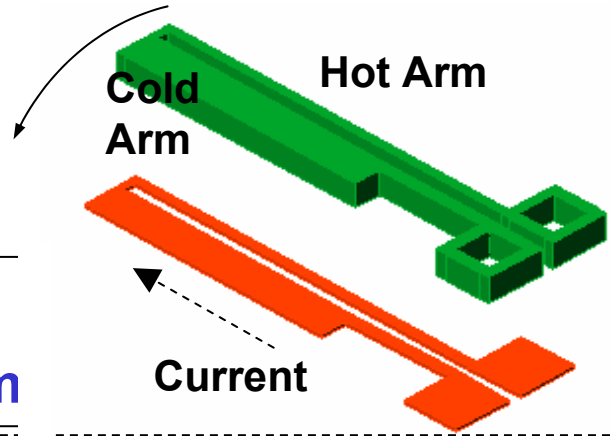
	Young's Modulus (GPa)	CTE (10^{-6} ppm)
Poly	169	2.9
Gold	80	14.3
SU-8	5	52.0
PDMS	0.7	310



$$\frac{h_s}{h_h} = \frac{20}{0.2} \approx 100$$

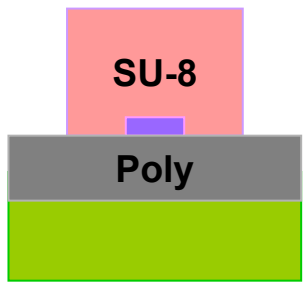
Actuation:
Electrothermal

Design:
Hot and Cold Arm



Structural: ***SU-8***

Sacrificial: ***Poly***



Fabrication:
Surface Micromachining

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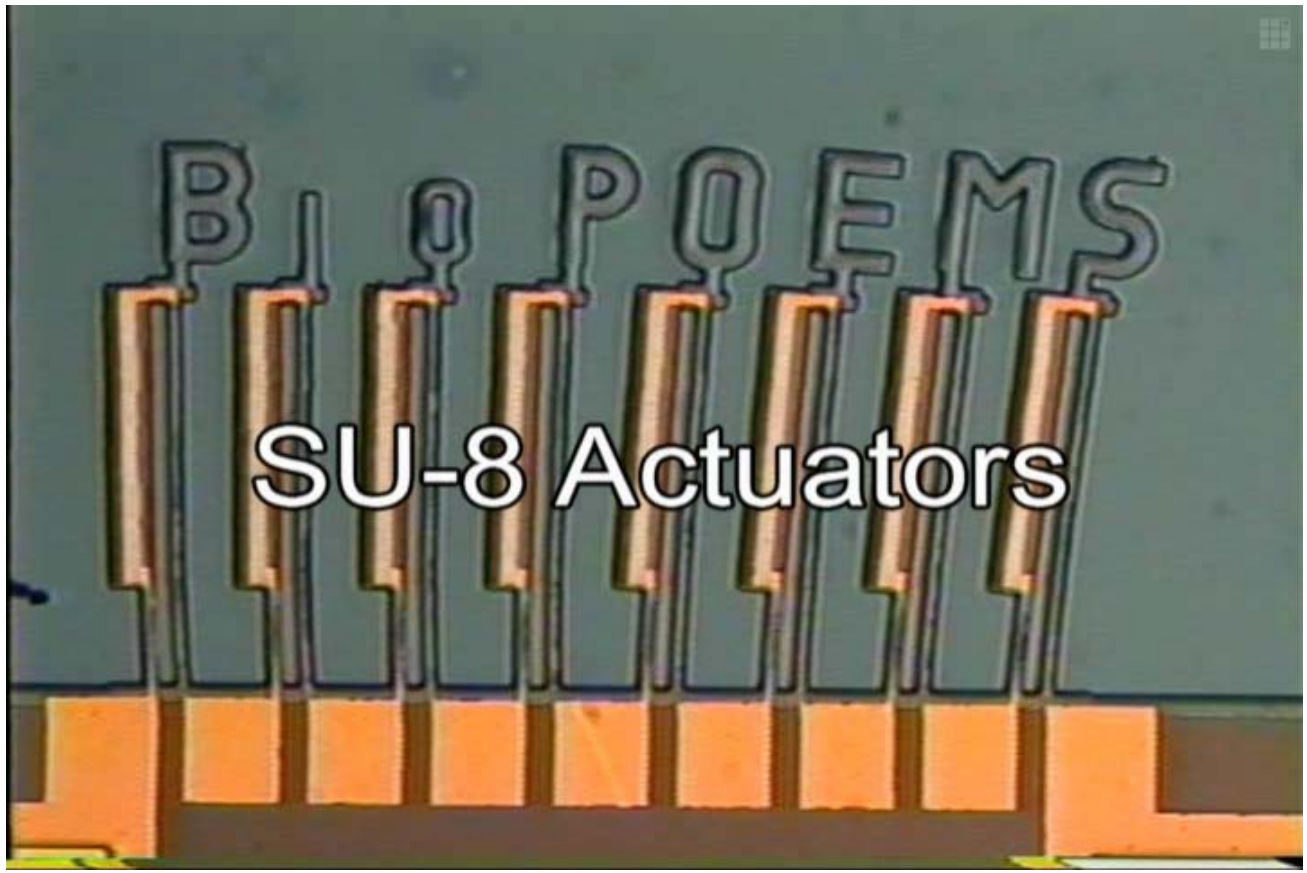
SU-8 Actuators In Action



*BIOPOEMS : **B**io-**P**olymer**O**pto**EI**ectro**M**echanical **S**ystems

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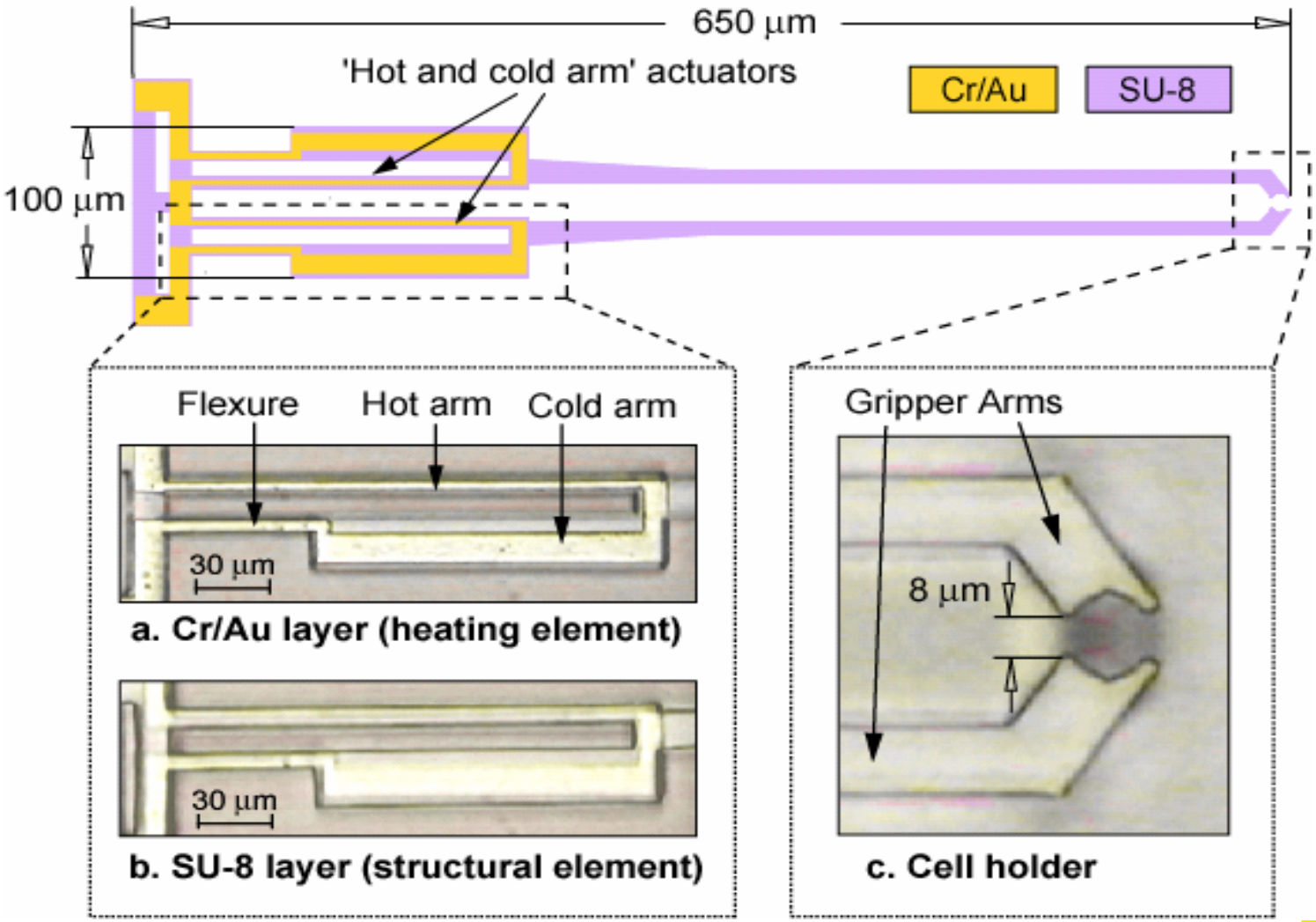
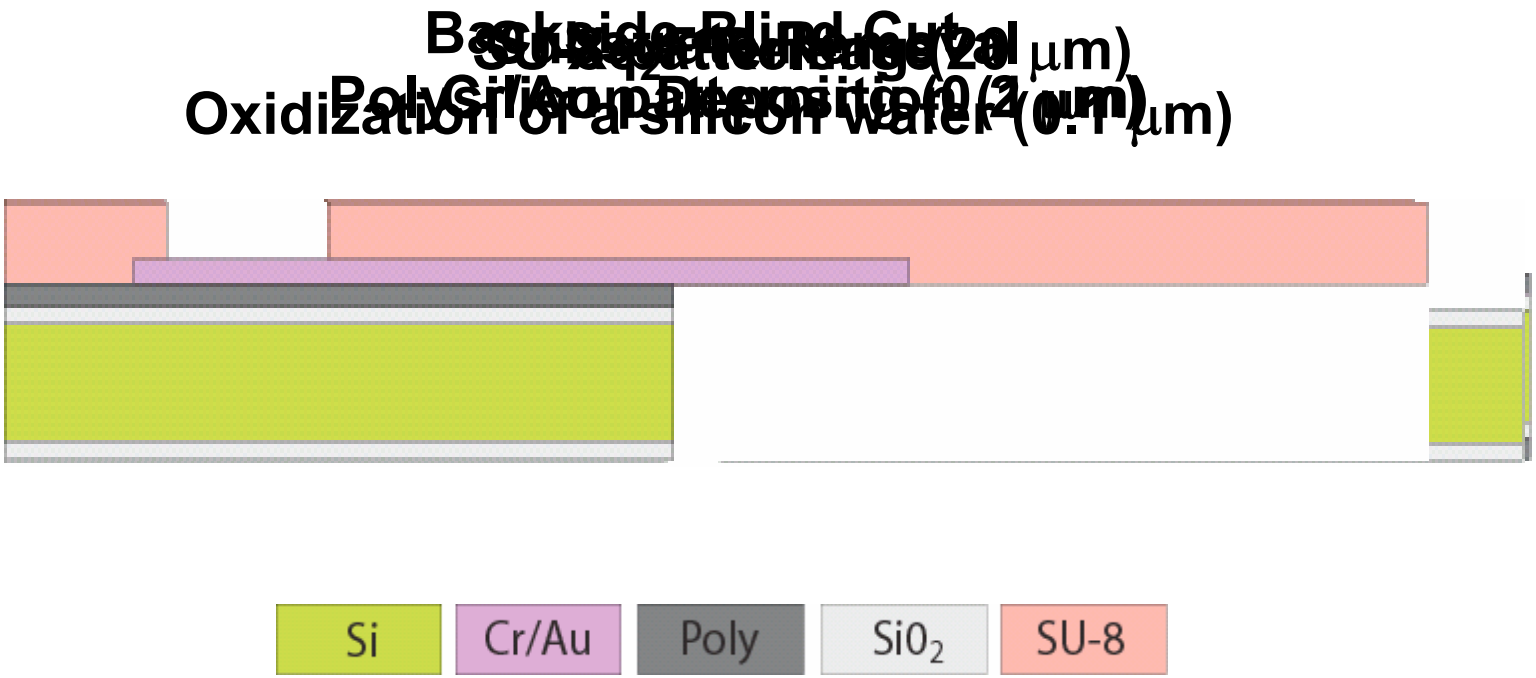
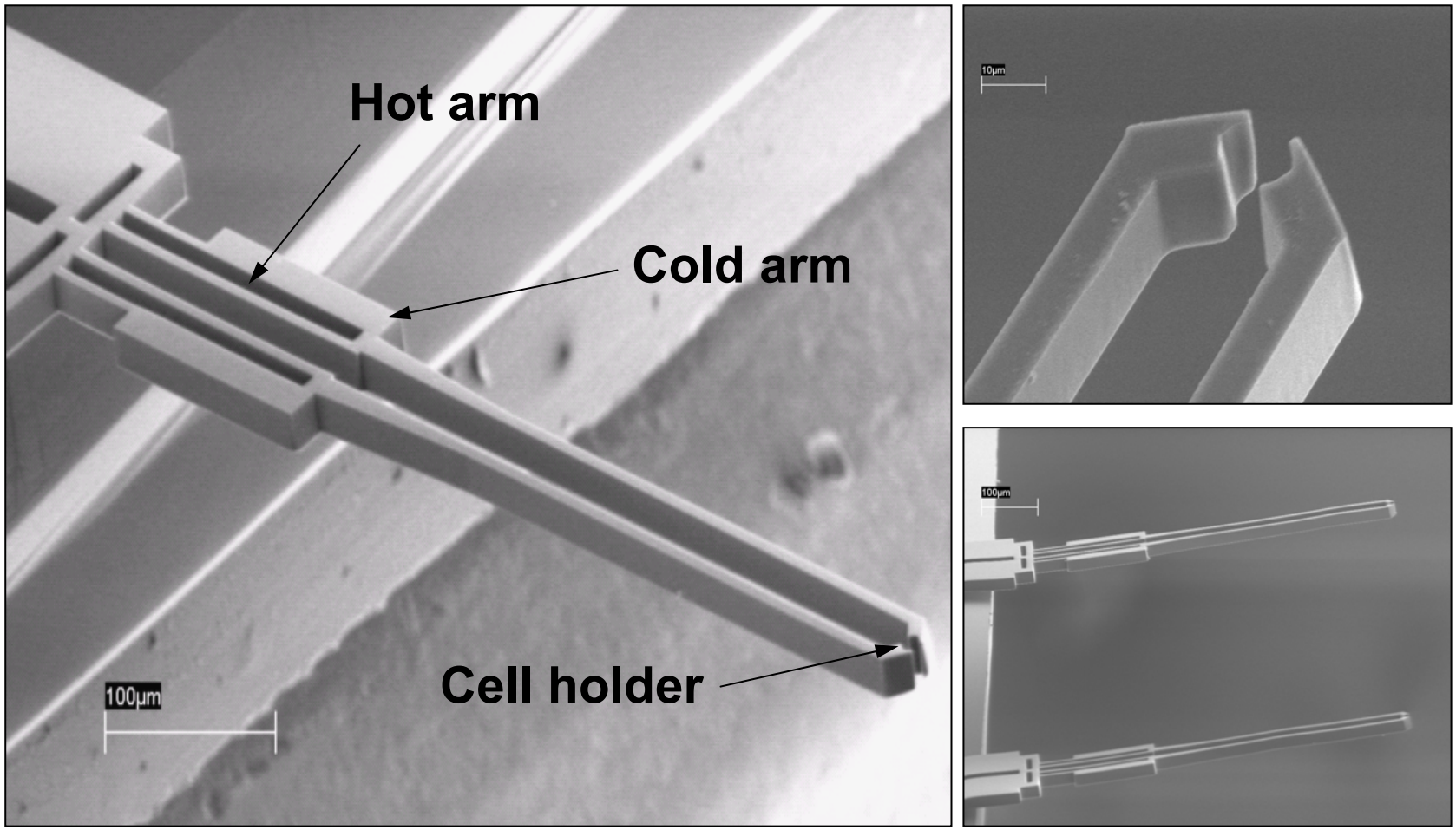
Microgripper Design



Fabrication Process



The Fabricated Device



Microgripper Performance

Critical Issues:

- **Temperature at the Tip**
  → **Minimize Cell Damage**
- **Maximum Temperature**
  → **Avoid Boiling**
- **Maximum Displacement**
  → **Cell Size**
- **Operation Voltage**
  → **Avoid Electrolysis**

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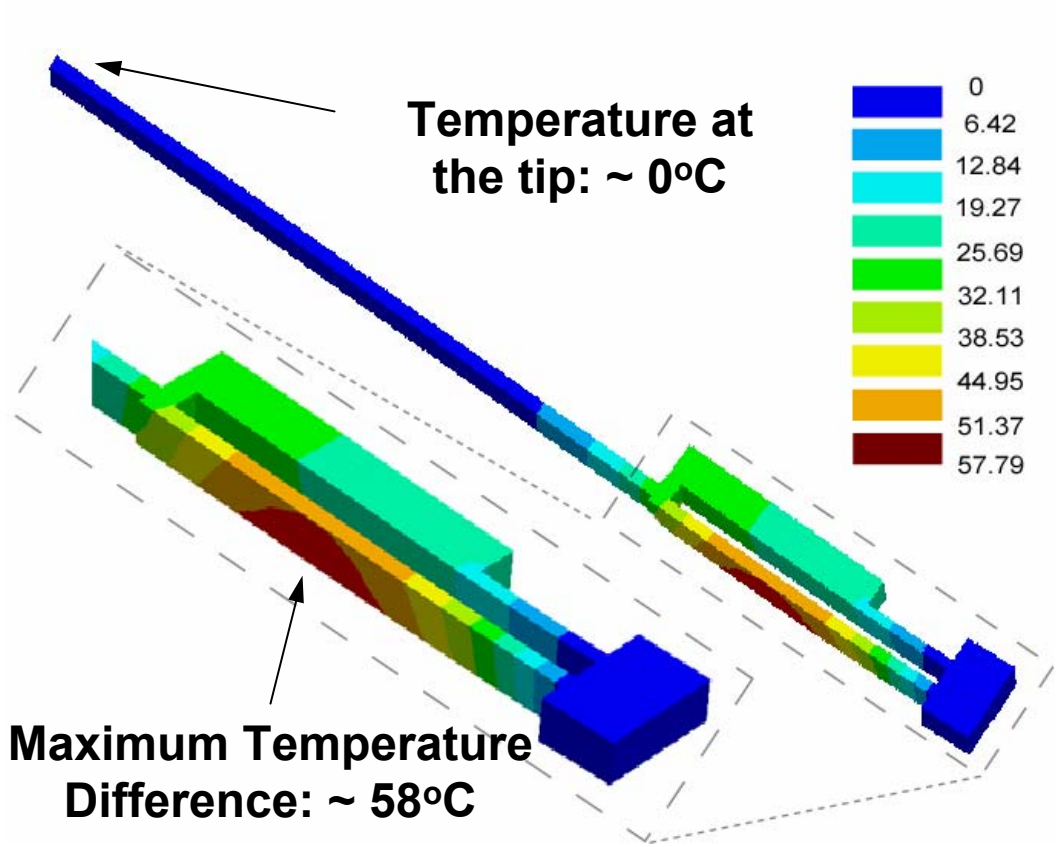
ThermoMechanical Modeling (ANSYS)

- **Negligible temperature difference at the tip**
- **20 μm total gripper opening (at maximum temperature difference of ~58°C)**
- **1.4 μm out of plane displacement**



Convection Coefficient assumed: h= 200 W/m²K (water)

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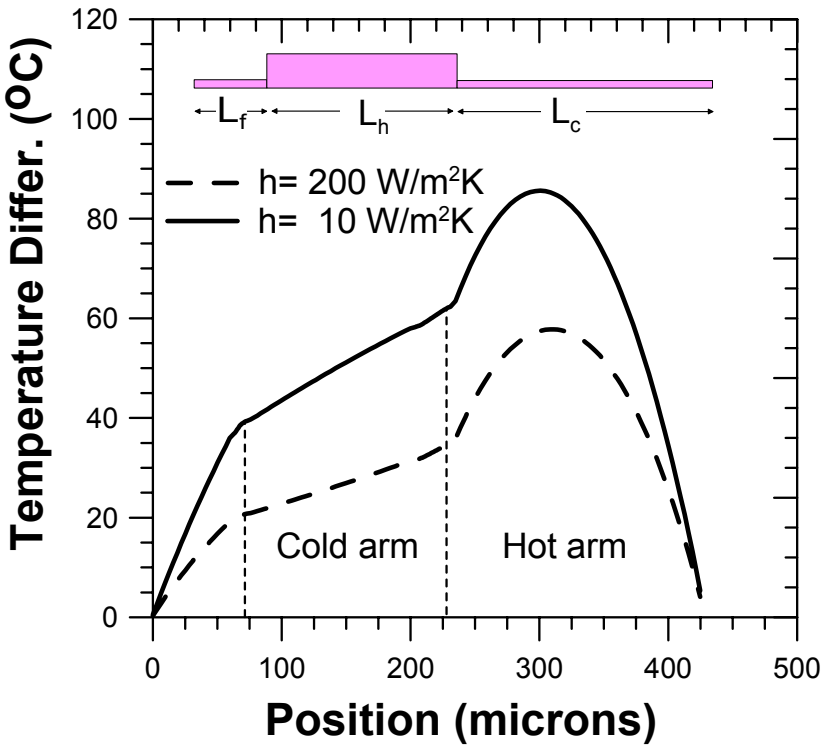
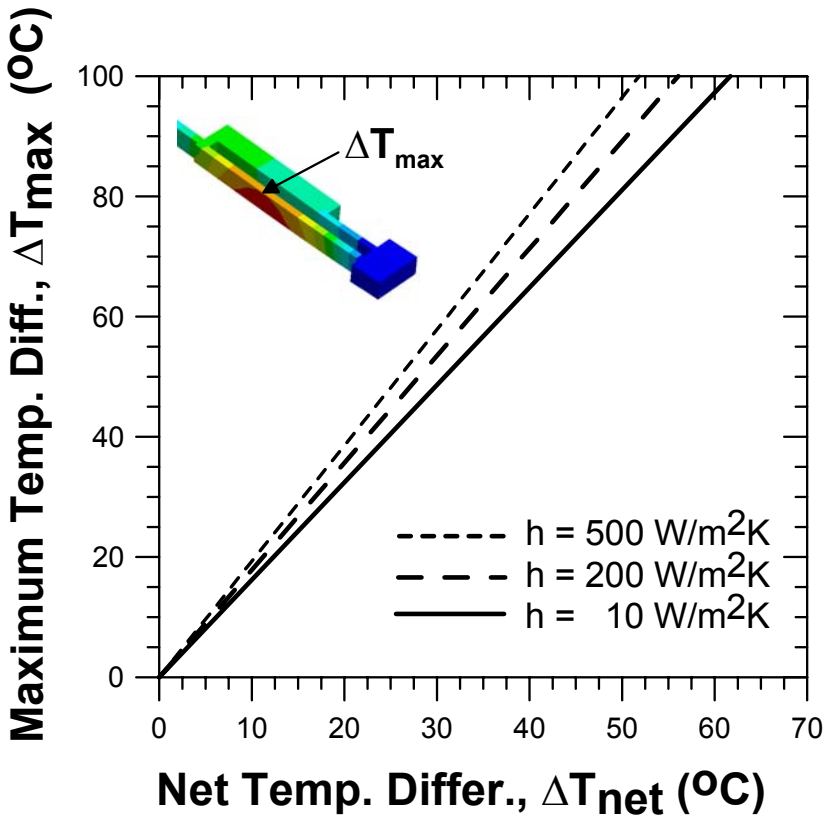
Simulation Results (ANSYS)

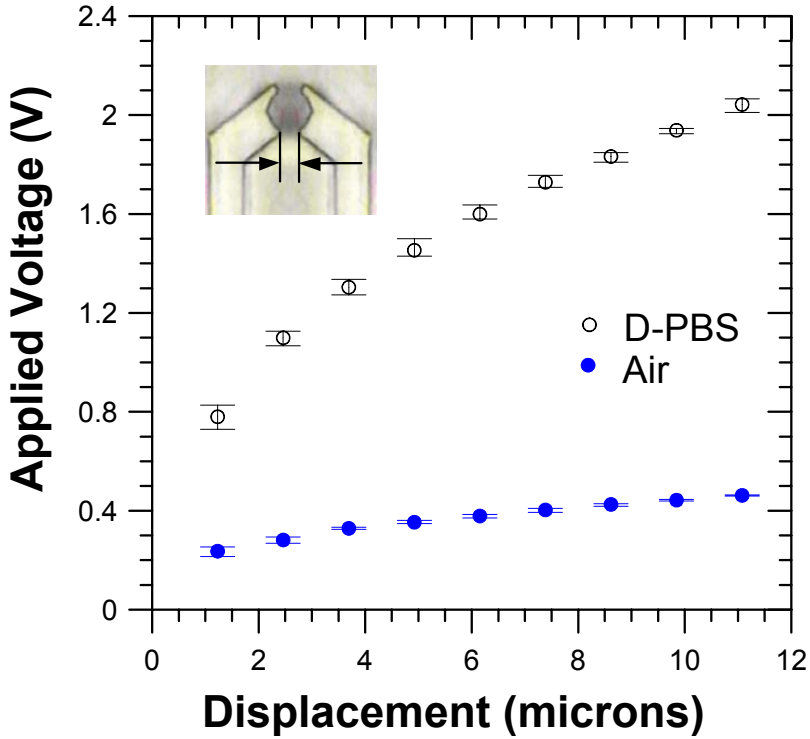


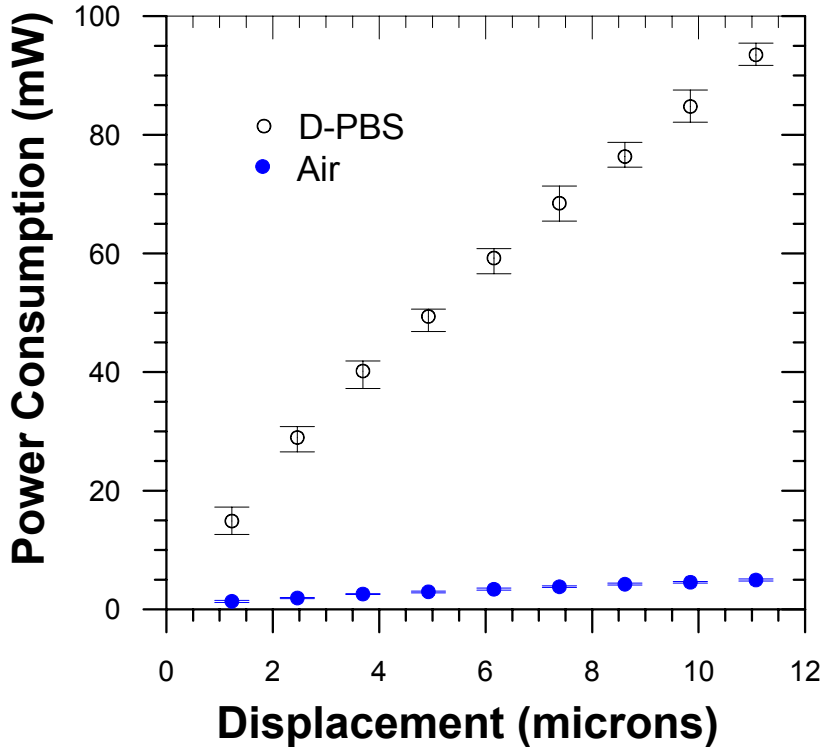


Net Temperature Difference: $$\Delta T_{net} = \frac{1}{L_1 + L_2 + L_3}\left[\int_0^{L_h} T_{hot}\,dx + \int_0^{L_c} T_{cold}\,dx + \int_0^{L_f} T_{flexure}\,dx\right]$$

Maximum Temperature Difference: $$\Delta T_{max} \approx 1.5\ \Delta T_{net}$$

Operation in Aqueous Environment *(experimental)*





- **Operation voltage: ~ 1.5 - 2 V in D-PBS (11 μm displacement)**
- **No electrolysis is observed**

**** D-PBS: Dulbecco's phosphate buffered solution***

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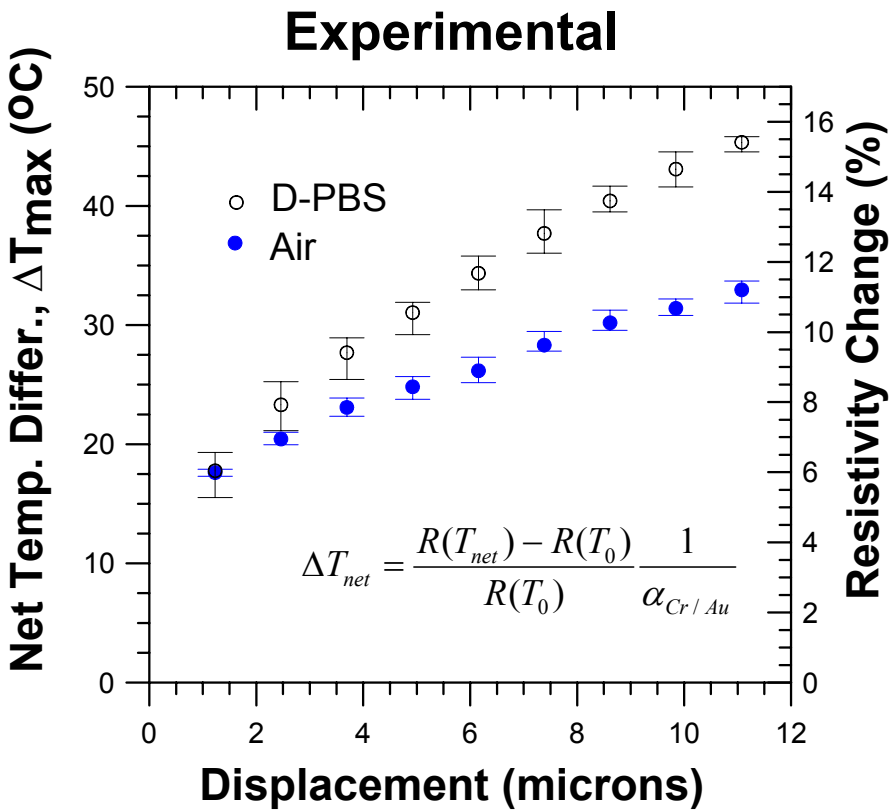
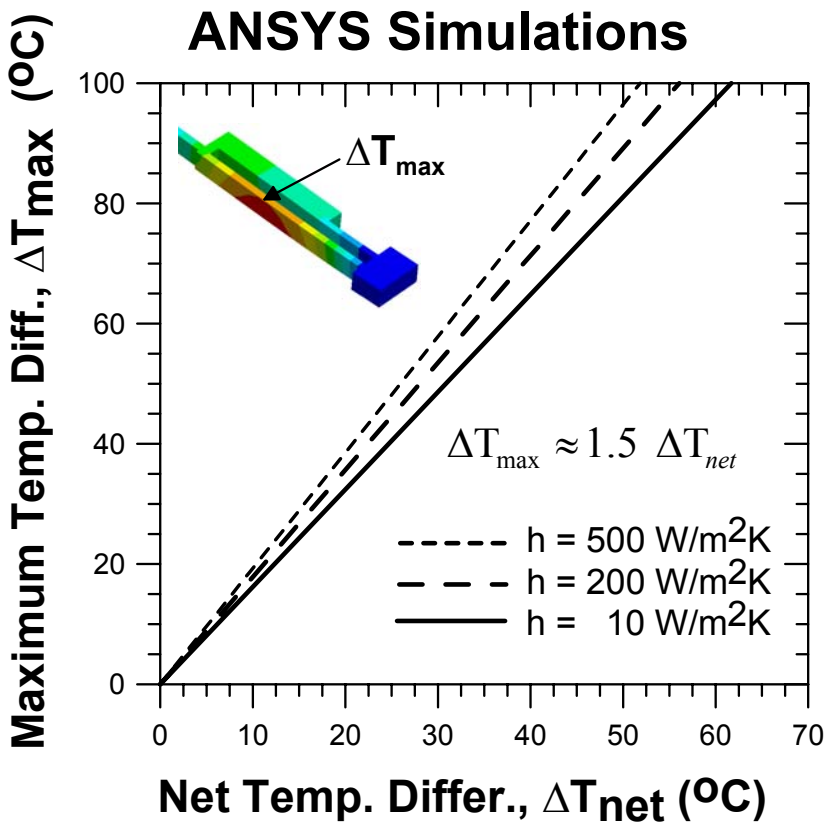
ThermoMechanical Analysis





- ΔT_{net} < 45°C for the full range of motion (11μm)
- ΔT_{max} < 65°C (extracted from simulations)

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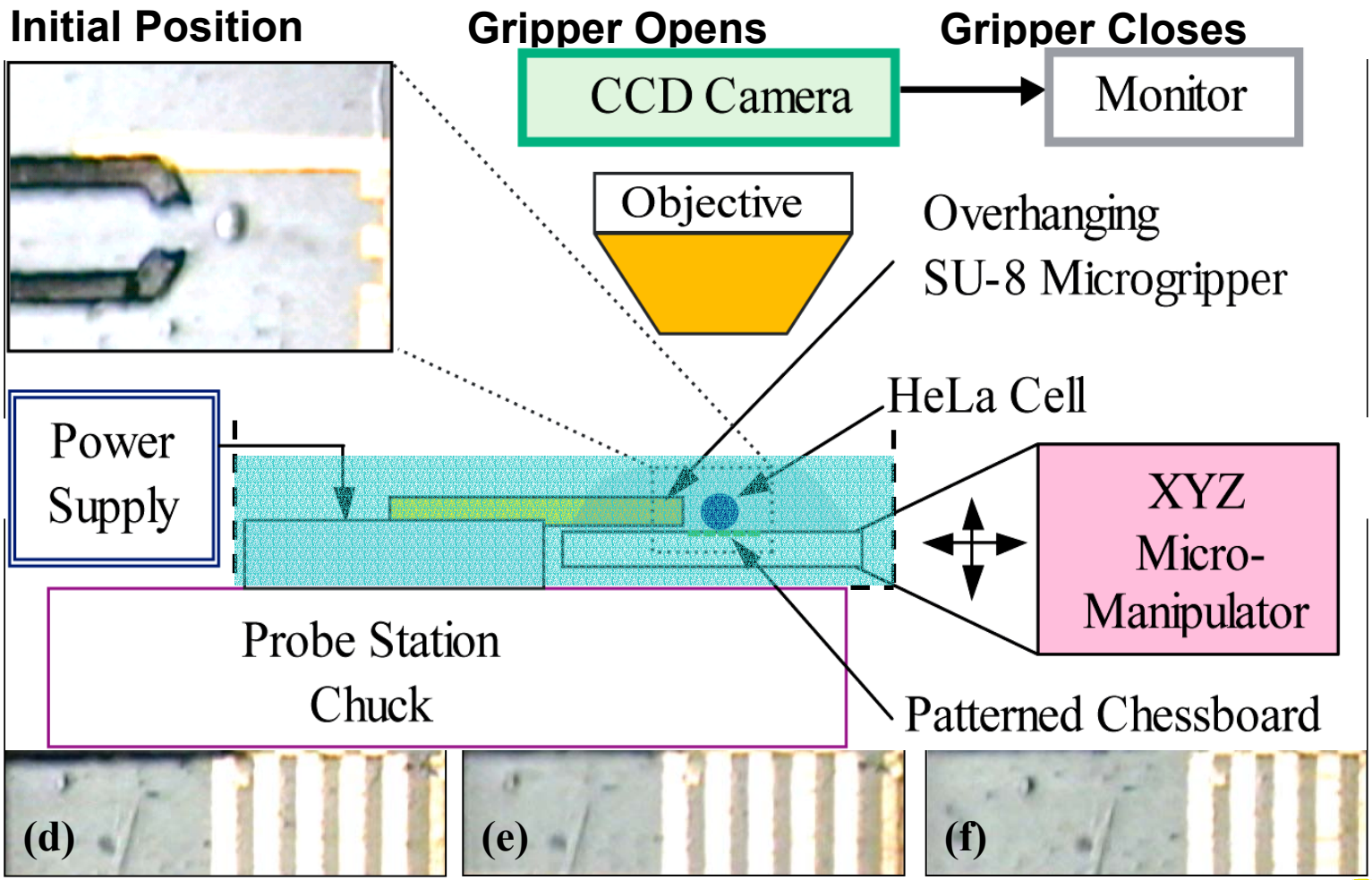
Single Cell Manipulation



Conclusions

Property	Specifications	Comments
Actuation	Electrothermal	• 'Hot and Cold Arm' design
Material	SU-8	• CTE = 52×10^{-6} ppm
Fabrication	Surface Micromachining	• Two Mask Process
Operation Environment	Air, Physiological Media	• Single Cell Manipulation in Solution
Operation Voltage	0.3 V (air) 1.6 V (liquid)	• No electrolysis observed • AC can also be used
Gripper Opening	11 μm	• Able to grasp cells 8-20 μm in diameter
Power Consumption	3 mW (air) 60 mW (liquid)	• 5-10 times lower than similar poly-based actuators

Acknowledgements: **DARPA (BioFlips program)**

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