Polymer Based Micro sensors and actuators in Biomedical Applications

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University of Washington
Micro Technology Laboratory
Our Goal

Integration of current MEMS and photonics technology in biomedical applications
Federal estimates predict that health care spending will surpass the $2 trillion mark in the next decade. Within the health care technology, biomedical device is one of the fastest growing segments.

Advance in sensor and transducer technology allows:

- Mass production (lower cost, high throughput, disposable)
- Miniaturization (increase sensitivity, portability, new diagnostics tools)
<table>
<thead>
<tr>
<th>PhD Students</th>
<th>Master Students</th>
<th>Undergraduates</th>
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<tbody>
<tr>
<td>Joe Ho, ME</td>
<td>Reynold Panergo, ME</td>
<td>Steve Evans Physics</td>
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<tr>
<td>Chen-Shen Huang, ME</td>
<td>Jiang Shiao, ME</td>
<td>Jeff Dee, Chem E</td>
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<tr>
<td>Chu-Yu Huang, ME</td>
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<td>Benjamin Estroff, EE</td>
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<td>Michael P. Weller,</td>
<td></td>
<td>Raymond Chung, pre-engr</td>
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<td>Architecture</td>
<td></td>
<td>James Etzcorn, pre-engr</td>
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<td></td>
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<td>Hamed Khoojinian, pre-engr</td>
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<td></td>
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<td>Aimi Ahmad-Shukri, pre-engr</td>
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<td>Anna Leung, pre-engr</td>
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</tbody>
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**Staff**

Christopher Galvanin, graphic design  
Daniel Ortiz, Physics  
Christopher lee, Physics  
Abram Clark
Collaborators

- PNETAX CO.
- University of Washington Human interface laboratory
- Cyma Corp.
- RR&D Center of Excellence for Limb Loss Prevention and Prosthetic Engineering at the VA Puget Sound Health Care System in Seattle
- UW medical school
- University of Washington Material Science Organic Functional Polymers Laboratory
- UW mechanical Engineering Vibration and Dynamic Laboratory
- University of Washington Media Center (architecture department)
- Carnegie Mellon University
- National Central University
- National ChengKong University
- National Huwei University of Science and Technology
- Southern Taiwan University of Technology
Self-Configurable Modular Robot

self-configuring building block to explore the potential uses of dynamic structures
Dynamic Structures

Espresso stand during the day and living quarter at night

Self-Configurable Modular Robot

W.-C. Wang
Block constructed using Rapid Prototype Technique

Self-Configurable Modular Robot

W.-C. Wang
Pallet to Wall Action

Self-Configurable Modular Robot

W.-C. Wang
Wall to Window
Liquid Ejector

- Rising Liquid Cylinder
- Liquid/Air Interface
- Beam Diameter at Focal Plane
- Surface Tension
- Acoustic Wave

**Droplet Formation due to Focused Acoustic Wave**

- Function of Radiation Pressure & Surface Tension
- Radiation Pressure \( (2I_f/V_a) \)
- Droplet Diameter ~ Beam Diameter at Focal Plane
Fabricated Device
(Micromachined Lensless Liquid Ejector)

Transducer Specifications
- RF Frequency: 300 MHz
- ZnO Thickness: 10.55 µm
- Focal Length: 400 µm
- Half-Wave-Band Sources: 7
- Predicted Droplet Diameter: 5 µm
Time evolution of the liquid ejection process produced by our 600MHz SFAT with an RF pulsewidth of 30μsec
MEMS acoustic sensor-hotwire sensor (thermo-resistor)

Resistance

Temperature

Flow rate

Viscosity and Mass Flow Sensors

W.-C. Wang
Viscosity and Mass Flow Sensors

A Linear, Single Degree of Freedom System with Viscous Damping Model

\[(m + m_{\text{entrained}})x + (C_s + C_f)x + kx = f(t)\]
Viscosity Measurement

Regime of unseparated flow

Frequency (Hz)

Maximum displacement (db)

1/sqrt(ρμ)

X_max \propto 1/(ρμ)^{0.5}

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Viscosity and Mass Flow Sensors
For small flow rate, $Re < 30$, experimental result show

$$\frac{1}{x_{\text{max}}} \propto V^{1.27}$$

Mass Flow Measurement

Mass Flow Measurement

Viscosity and Mass Flow Sensors

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Different Submerged Depth

Experimental result

Simulation result from FEM model

Maximum displacement (dB)

Frequency (Hz)

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Viscosity and Mass Flow Sensors
Foot Ulcers Caused by Mechanical Trauma

- Vertical plantar pressure has been associated with the development of ulcers
- Others have postulated shear stress is an important component of ulcer development
  - little known about actual distribution
  - lack of validated commercially available shear sensor

Polymer based Pressure/Shear Sensor

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Developing a distributive optical sensor capable of:

- Simultaneously measuring vertical and horizontal loads
- Detecting the direction and the magnitude of the loads
- Creating a linear relationship between signal and applied load and without hysteresis.
- Leading to a multi-channel distributive pressure/shear sensor
- High spatial resolution
Polymer based Pressure/Shear Sensor

- Higher spatial resolution (250µm x 250µm)
Compare Normal & Flat Foot Plantar Pressure Distribution

- *High pressure (0.82 MPa) under the second metatarsal head*
- *Medial deviation of COP without the arch*

Normal Foot

Flat Foot

Polymer based Pressure/Shear Sensor

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Optical Scanner: Image Acquisition and Display

**Background:**
- Single cantilever beam actuated in both X and Y direction to provide raster scanning of images
- Function as image display with controlled pulse LED

**Application:**
- Alternative to current endoscopic devices which use bundle of optical fibers
- Portable image display device

**Current Design:**
- Microfabricated SU-8 Waveguide with 50x100 µm cross section
- Mounted on X-Y bimorph transducers
- 2-D Image Acquisition is achievable
Optical Scanner: MEMS Based Device

What needs to be achieved?

• An integrated system of light source, waveguide, actuators, control feedback are desired as the overall design implementation for the optical scanner.

Integrated MEMS Actuator:

• The design and fabrication of a MEMS actuator will be the next step in the process
• The device will integrate comb drives as a means of actuation
• Microfabrication of the actuators will utilize a Bosch DRIE Process and Wet Chemical Release Etch

2-D Comb Drive Actuator
2D Scan on ‘3 Bar’ Black Shape with Transparent Background

Top Figure:
3 Bar with Transparent Background
*square mesh is scanning area

Bottom Figure:
Intensity vs. Number of Scans

Sampling Rate: 100000 scans/sec
Horizontal Frequency: 25Hz
Horizontal Amplitude: 600mV
Vertical Frequency: 4.710kHz
Vertical Amplitude: 600mV
Display image using pulse modulation on input light source

Modulating frequencies on LED
Horizontal = 38.48 kHz
Vertical = 190.6 Hz
Dielectric Elastomer Actuator

- Electrodes on top and bottom
- High voltage is passed through the electrodes
- Positive and negative charges build up on the top and bottom acting as a capacitor

Once a high enough voltage is reached, the electrodes are forced together squeezing the elastomer

Under the resulting stress, the elastomer stretches
Demonstration
Diamagnetic Levitation

- No energy input required
- Can levitate at room temperature
- Potential applications:
  - Frictionless motor or generator
  - Levitated magnets
Contact Information

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