

MEMS Sensors for Biomedical Applications

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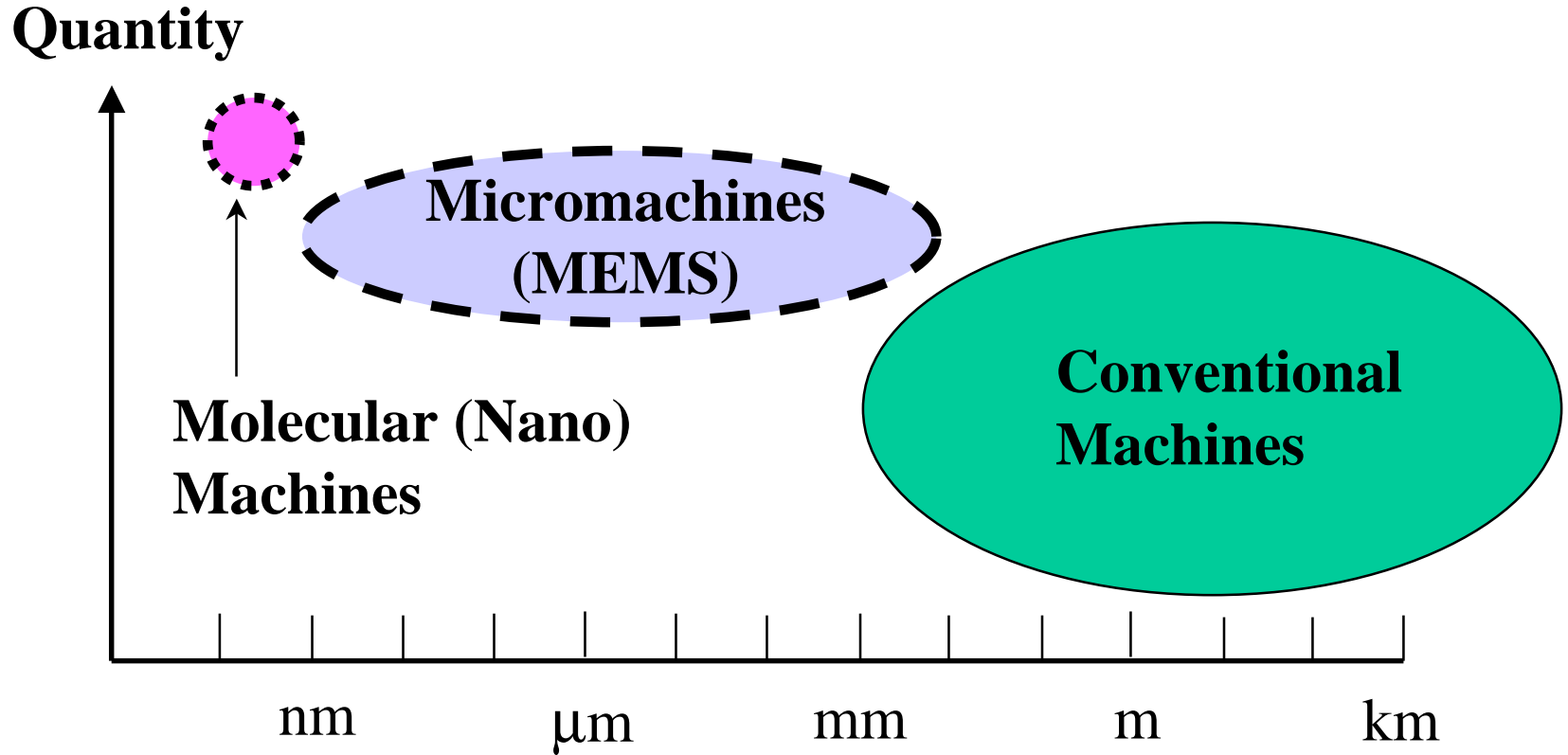
What is MEMS?

A Micro-Electro-Mechanical System (MEMS) is a **batch-fabricated (microfabricated) system** that contains both electrical and mechanical components with characteristic sizes ranging **from nanometers to millimeters**.

Other Names

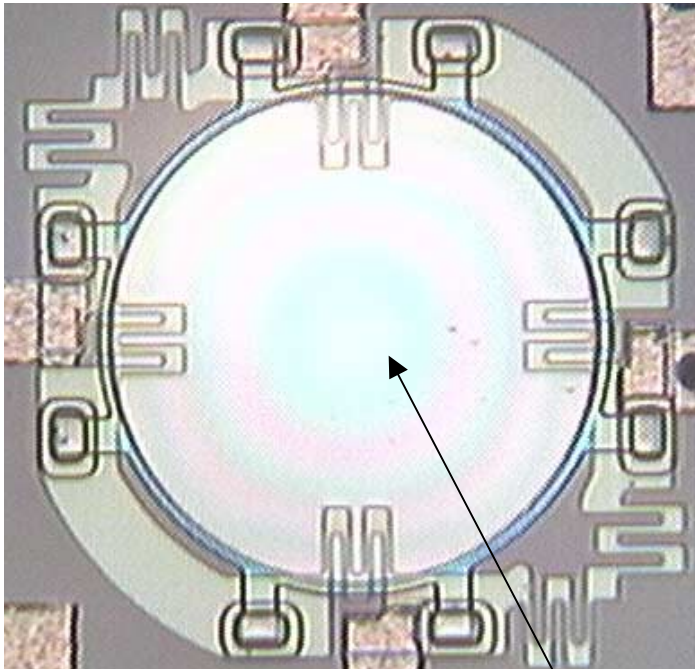
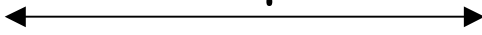
- In US: Microdynamics
- In Europe: Micro Systems (Technology)
- In Japan: Micromachines, MicroRobots

Machine Size

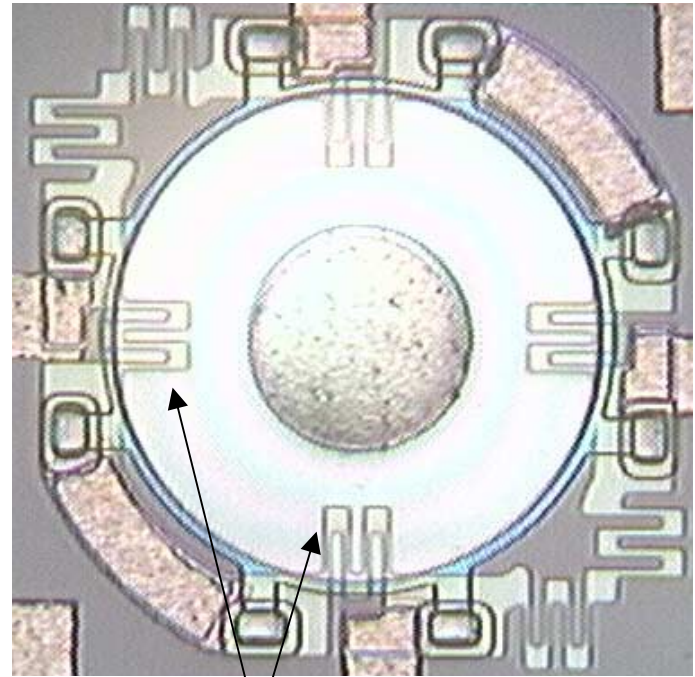


Pressure Sensors

200 μm

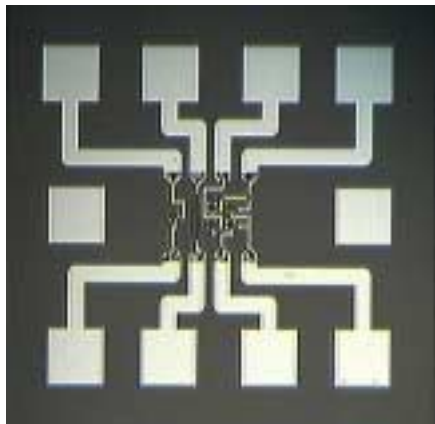


Nitride diaphragm



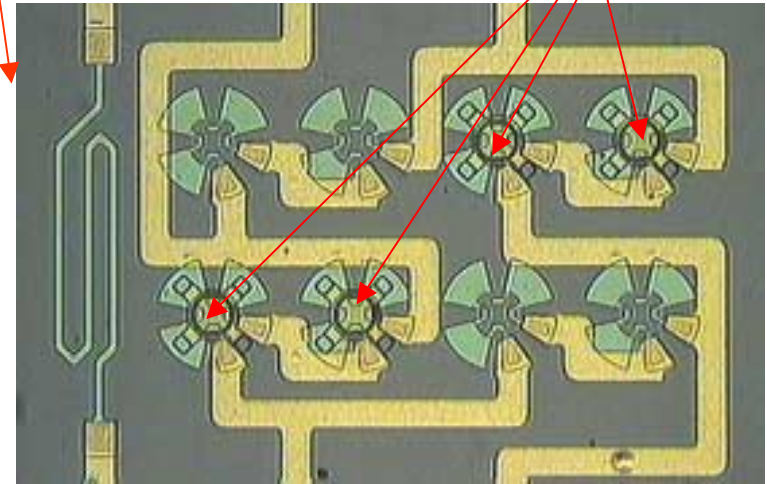
Poly strain gauges

Schlumberger Oil-Well Pressure Sensor

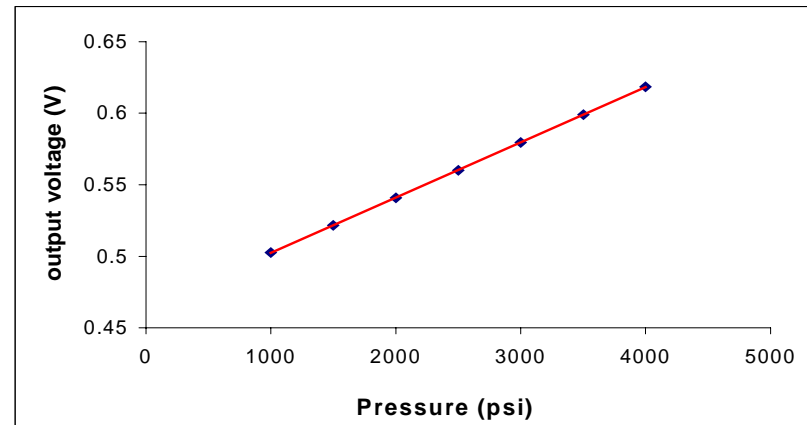


Polysilicon
thermistor

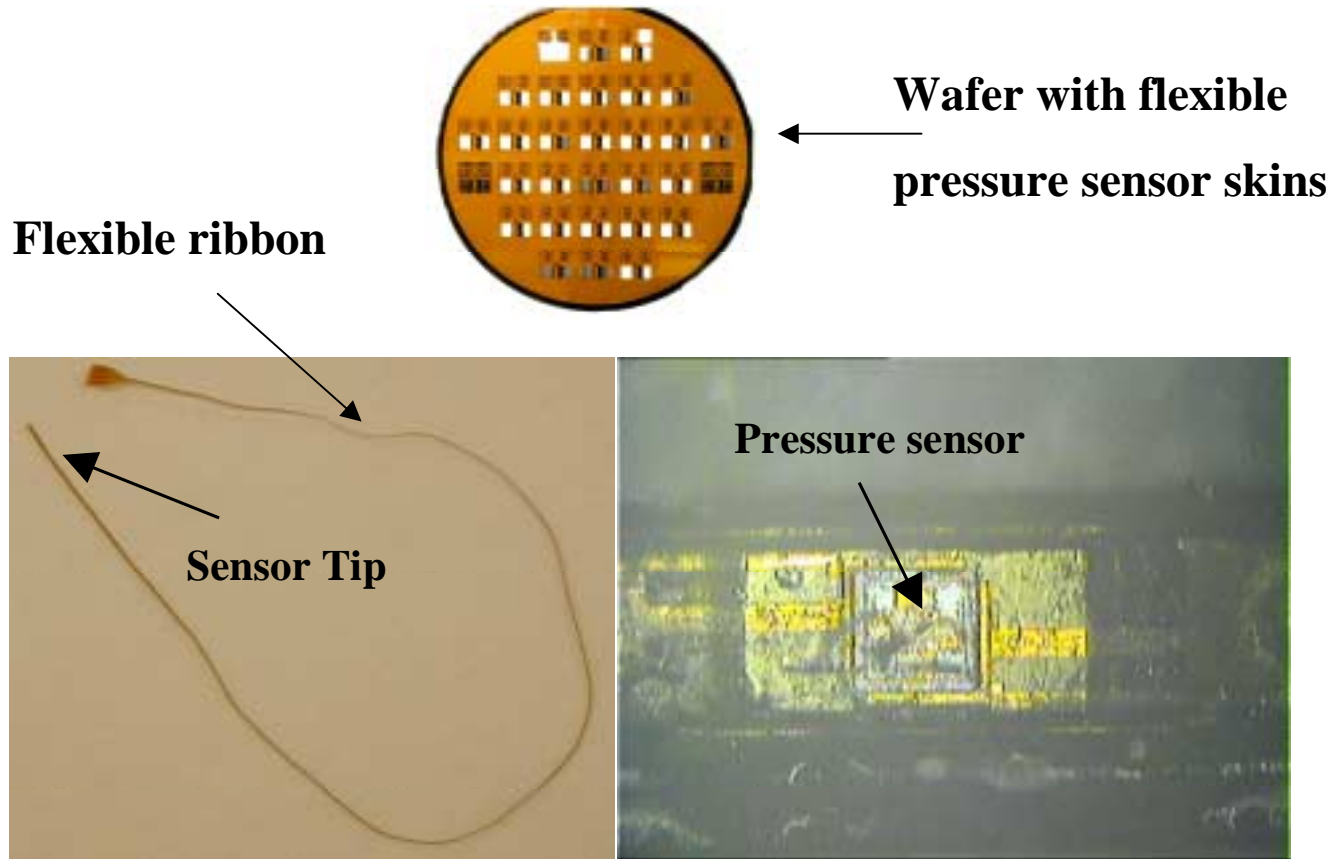
4 nitride
Diaphragms



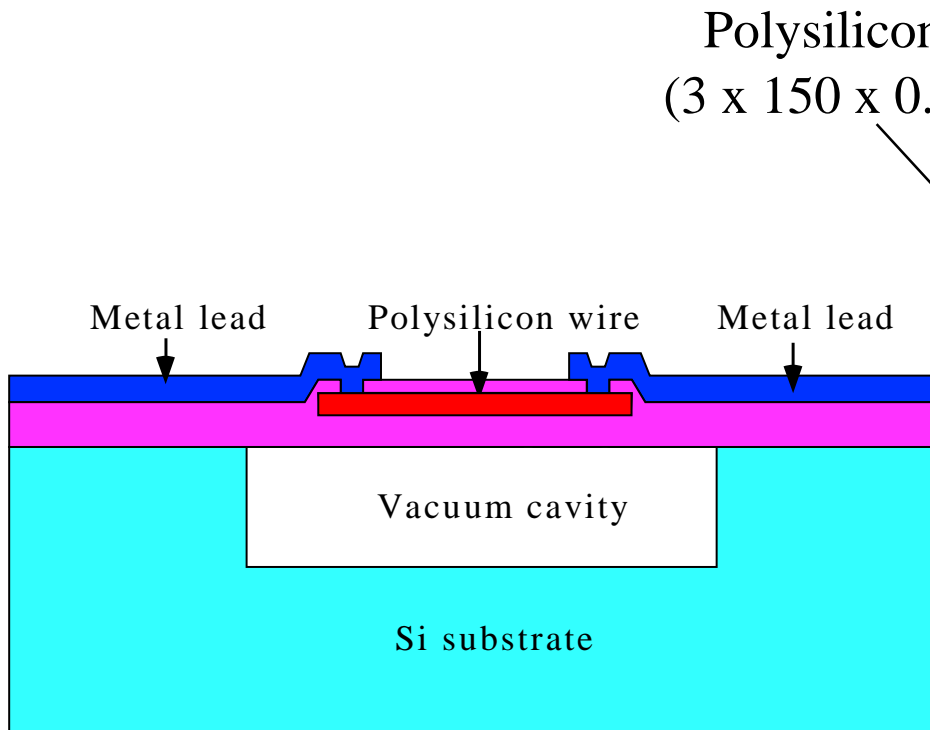
- 10,000 \pm 2 psi design
- Multi-diaphragm configuration



MEMS Pressure Sensor Probe for Intraocular Pressure Measurement



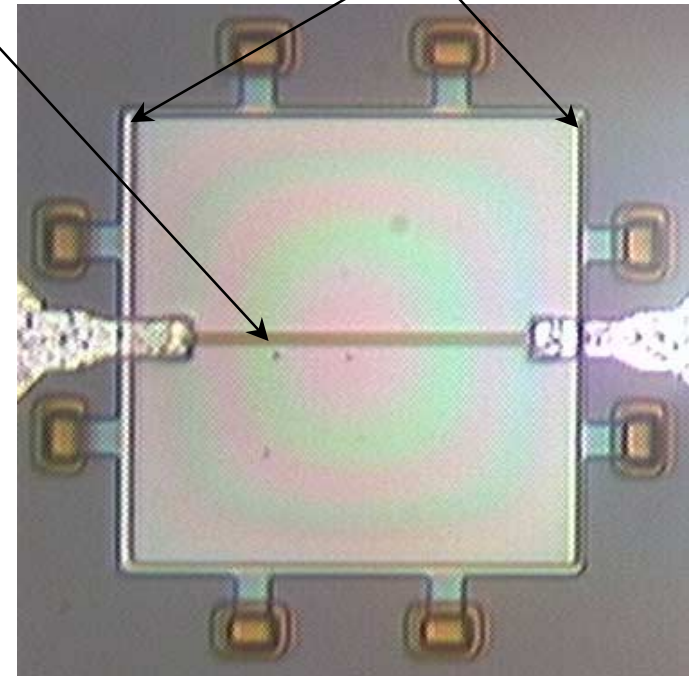
Vacuum-Insulated Shear Stress Sensor



Cross-section

Polysilicon Wire
($3 \times 150 \times 0.5 \mu\text{m}^3$)

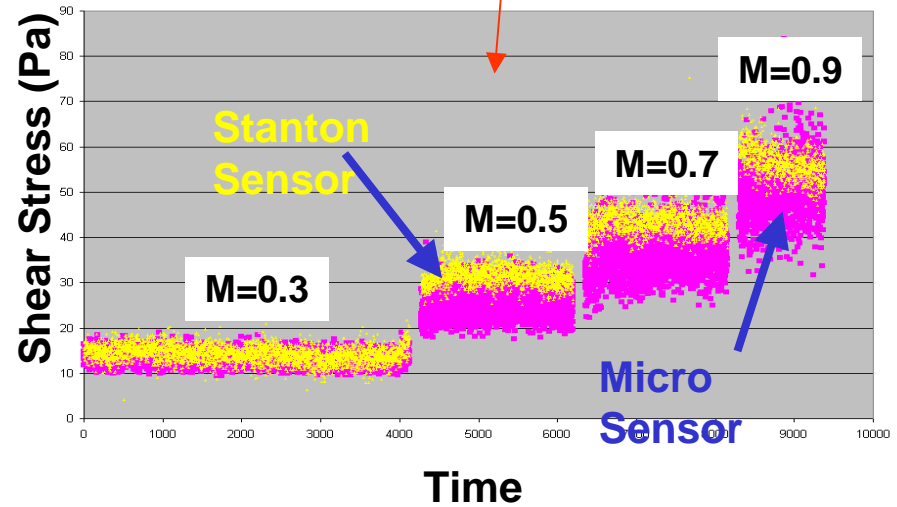
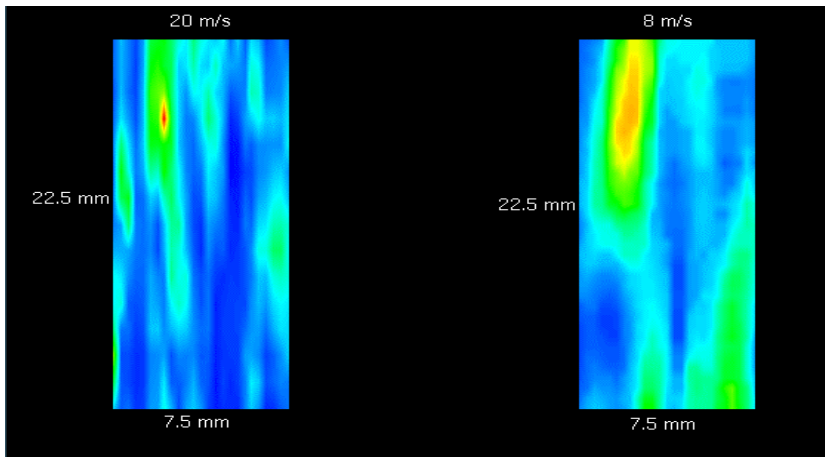
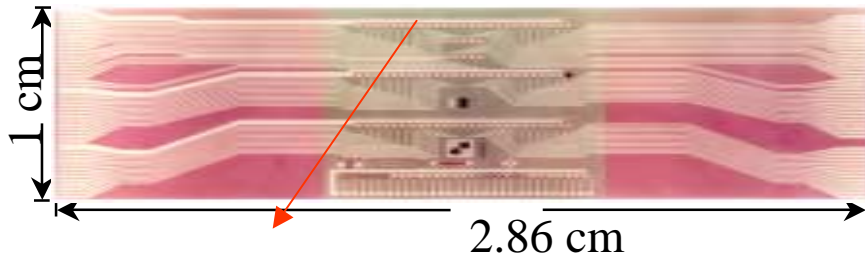
Vacuum Cavity
($200 \times 200 \times 2 \mu\text{m}^3$)



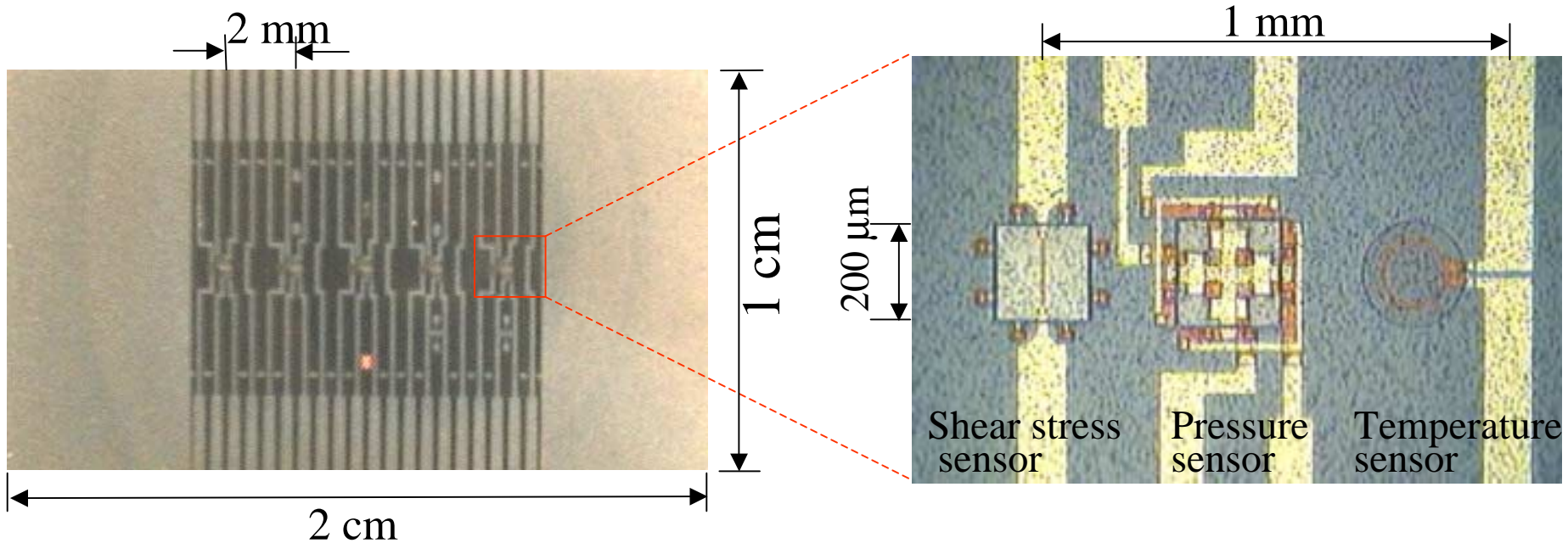
Photograph

Successful Test on NASA F 15

Shear-stress Sensor Imager

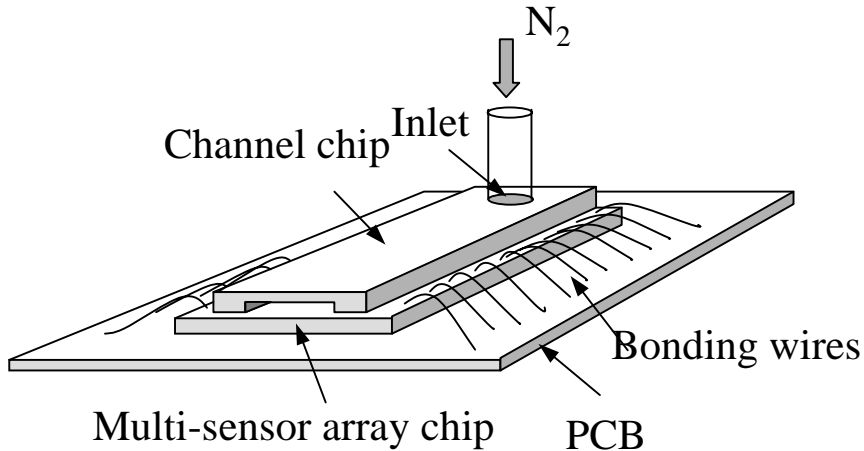


Multi-sensor chip: Pressure, Temperature and Flow



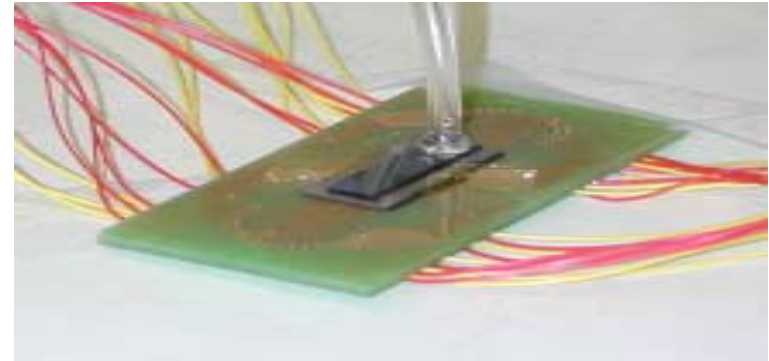
Five sensor clusters with a pitch of 2 mm.

MEMS Mass Flow Meter

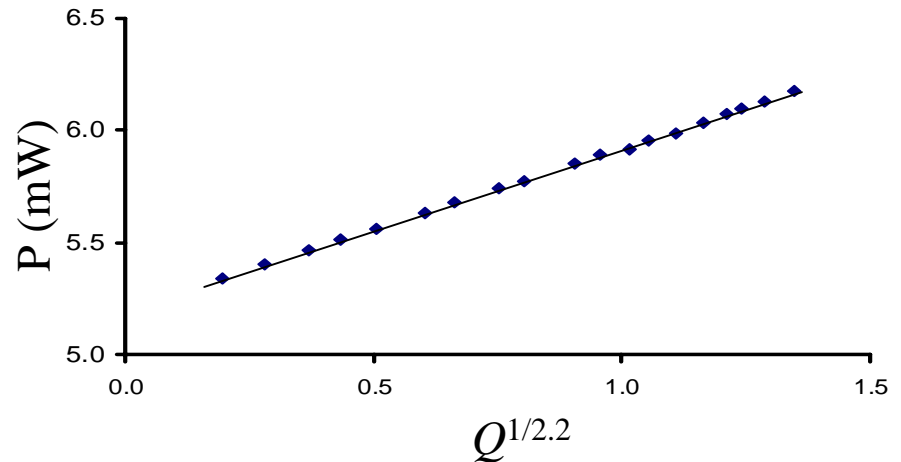


Schematic of packaged device

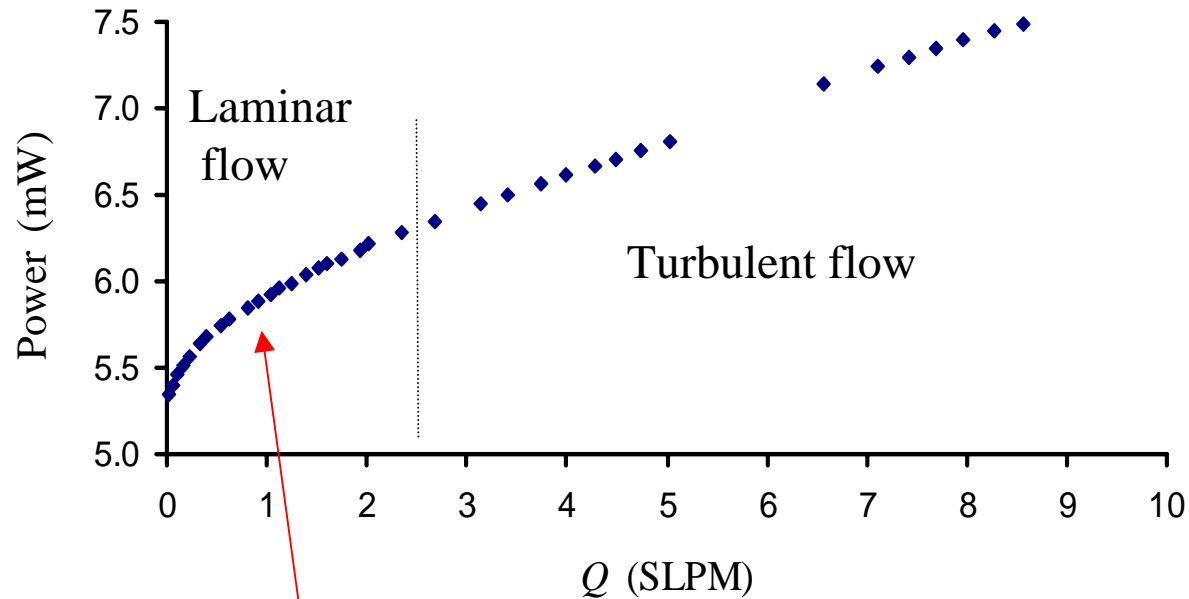
Channel width: 2.5 mm
Channel height: 0.2 mm
Channel length: 18 mm



picture of a packaged device

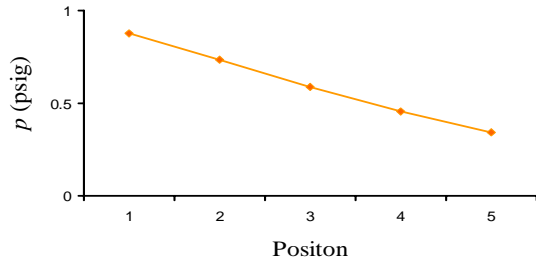


Calibration of the thermal flowmeter

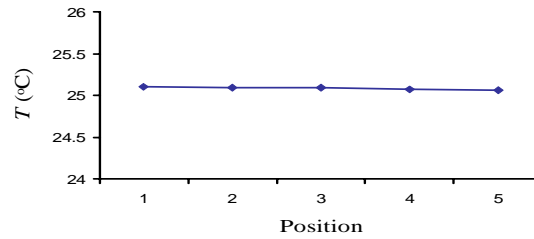


- Non-linear output

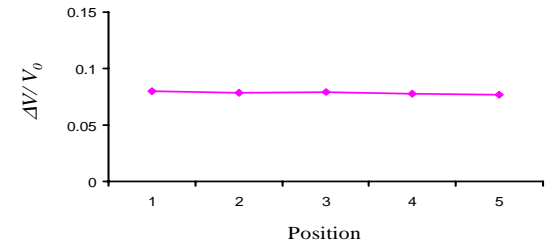
Measurement of channel flow



(a) Pressure distribution

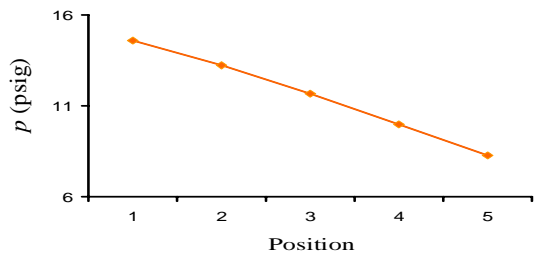


(b) Temperature distribution

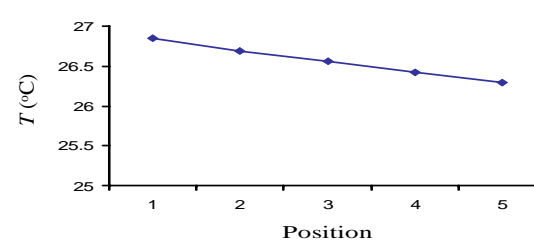


(c) Relative output change of shear stress sensors

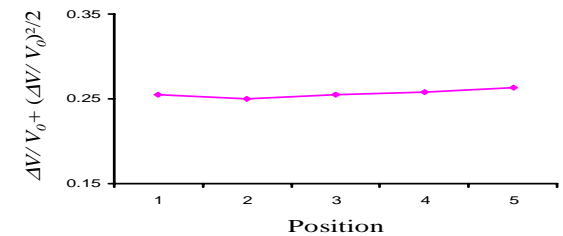
Measurement of fully developed incompressible channel flow (Mach number = 0.2)



(a) Pressure distribution



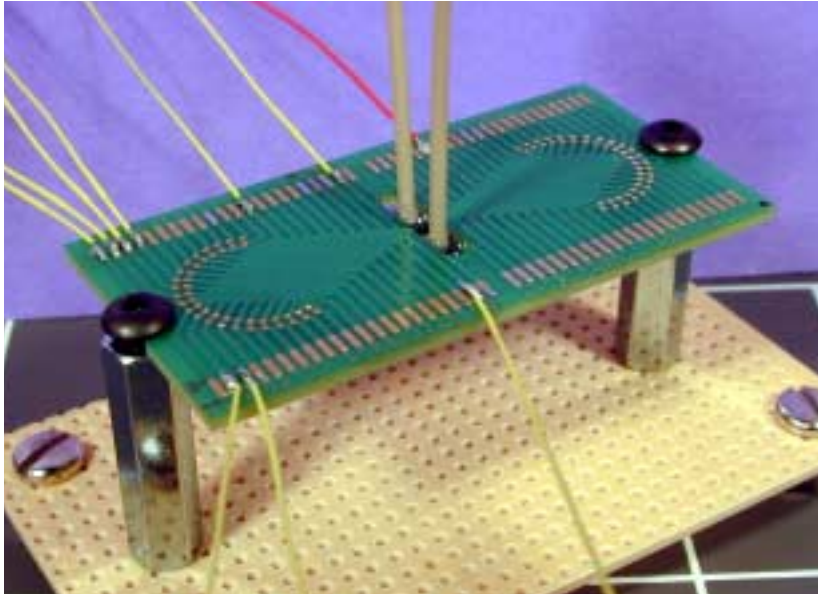
(b) Temperature distribution



(c) Relative output change of shear stress sensors

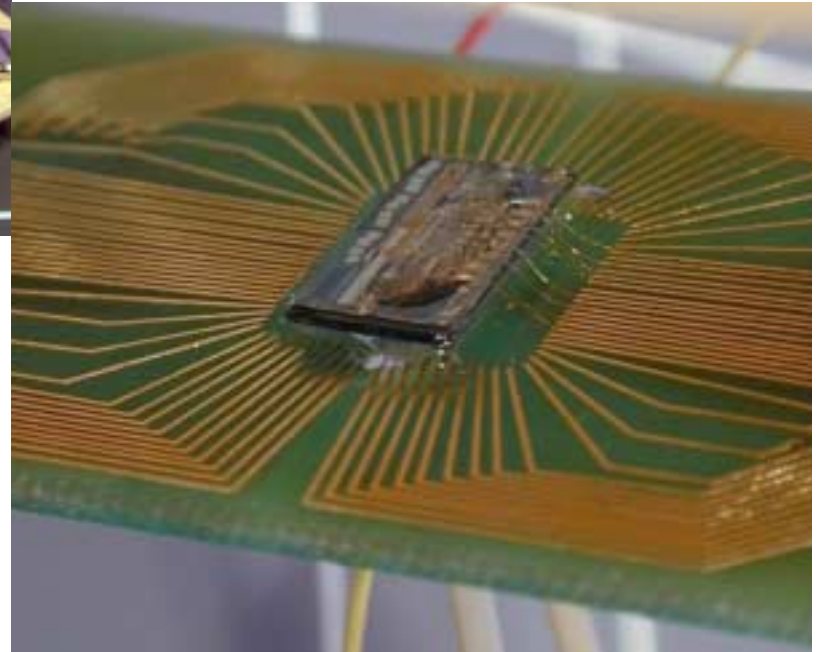
Measurement of fully developed compressible channel flow (Mach number = 0.6)

Microflow (μl) Sensor

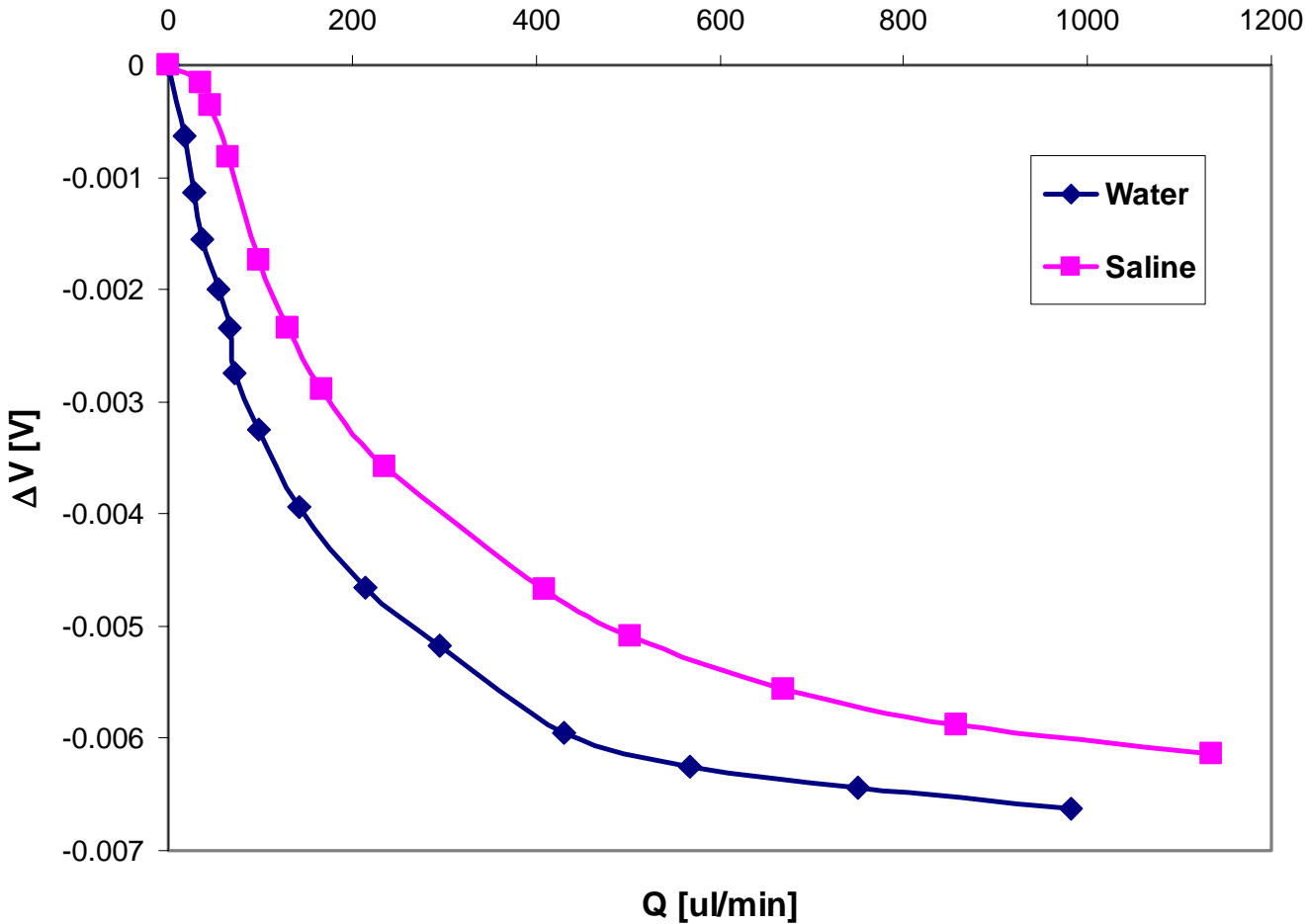


Top View

Bottom View



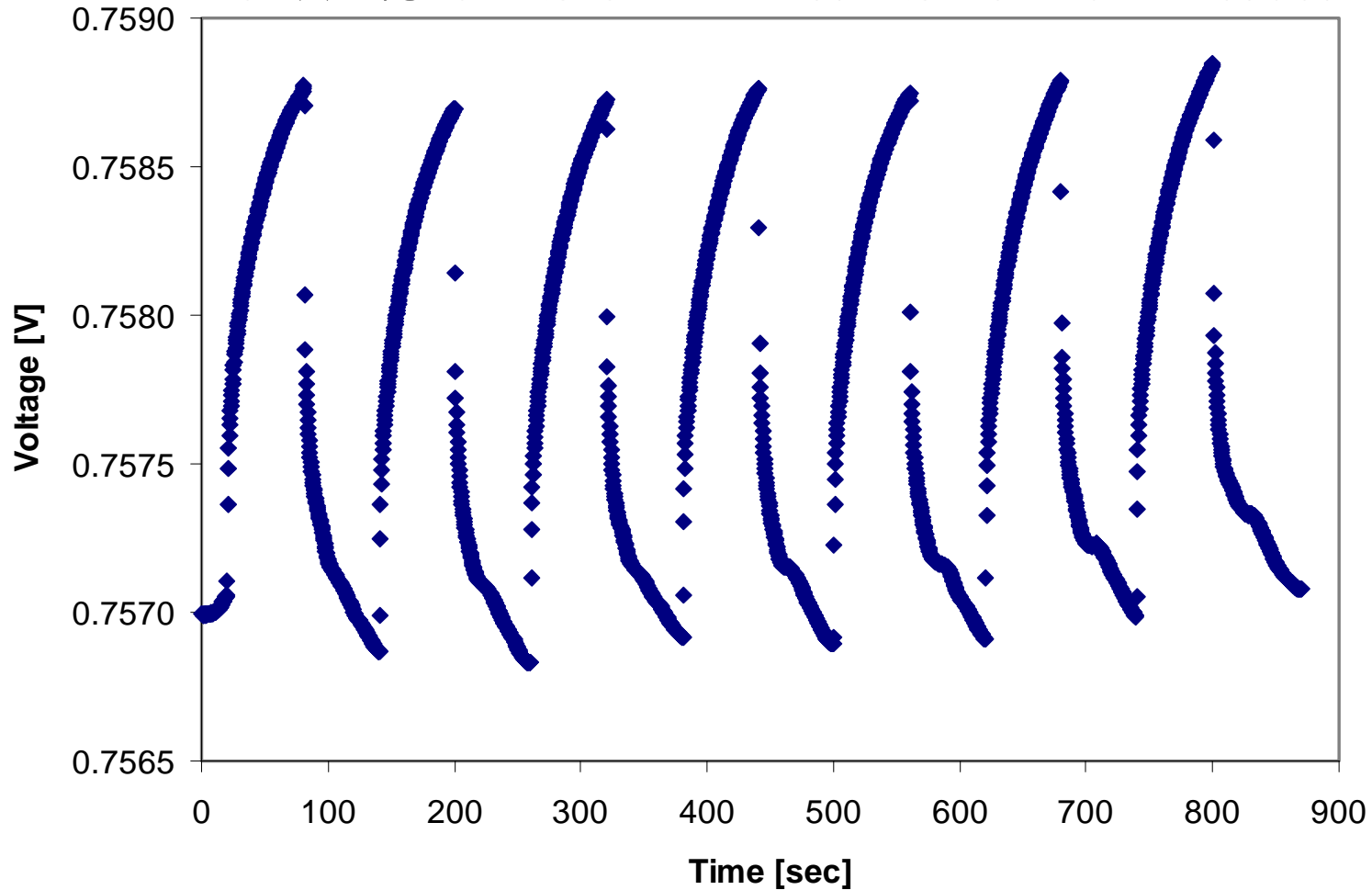
Flow Rate Data



30 mA
36 mW

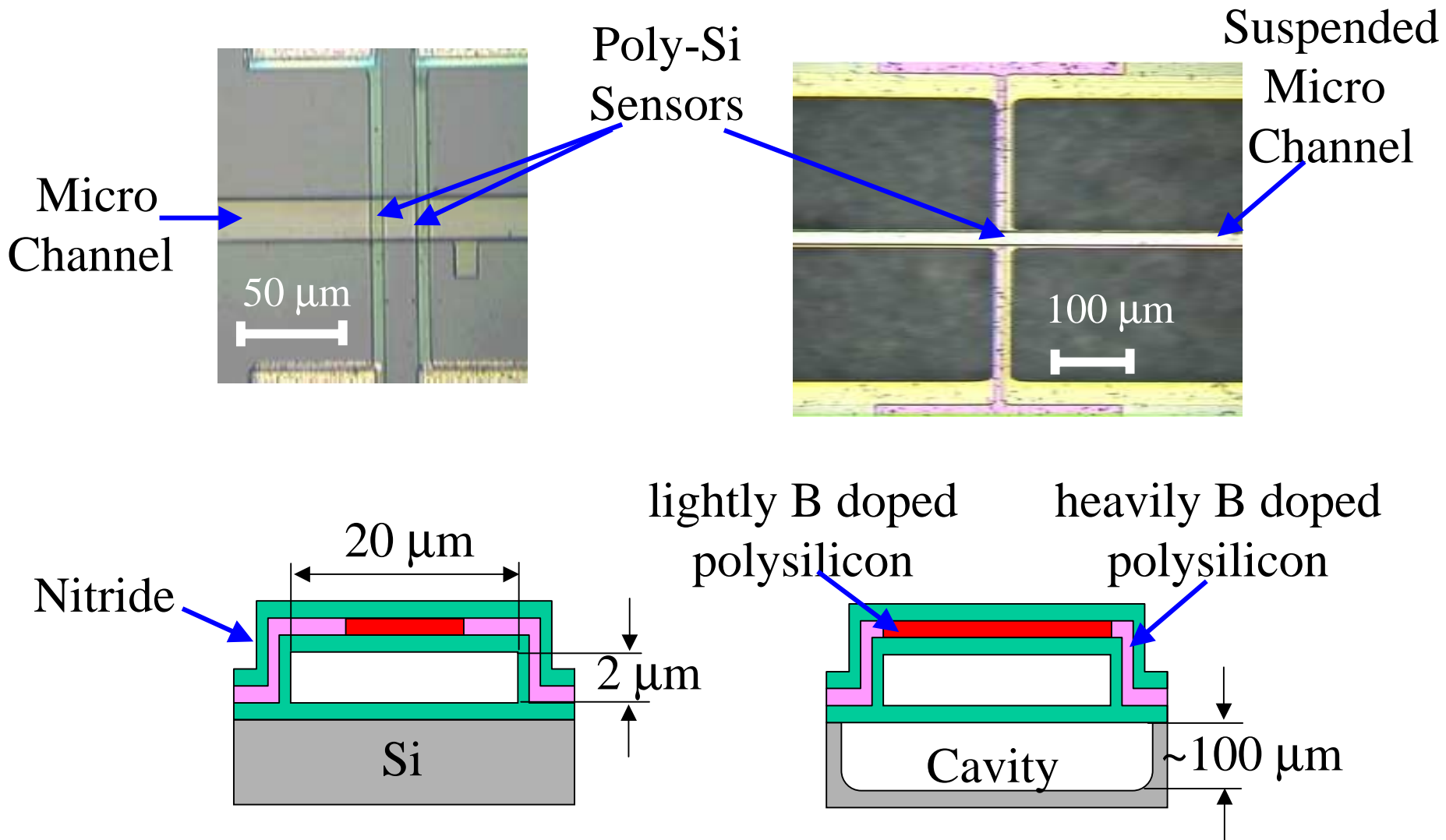
Measures flow rates up to 10 $\mu\text{L}/\text{min}$

Flow Sensor Transient Data

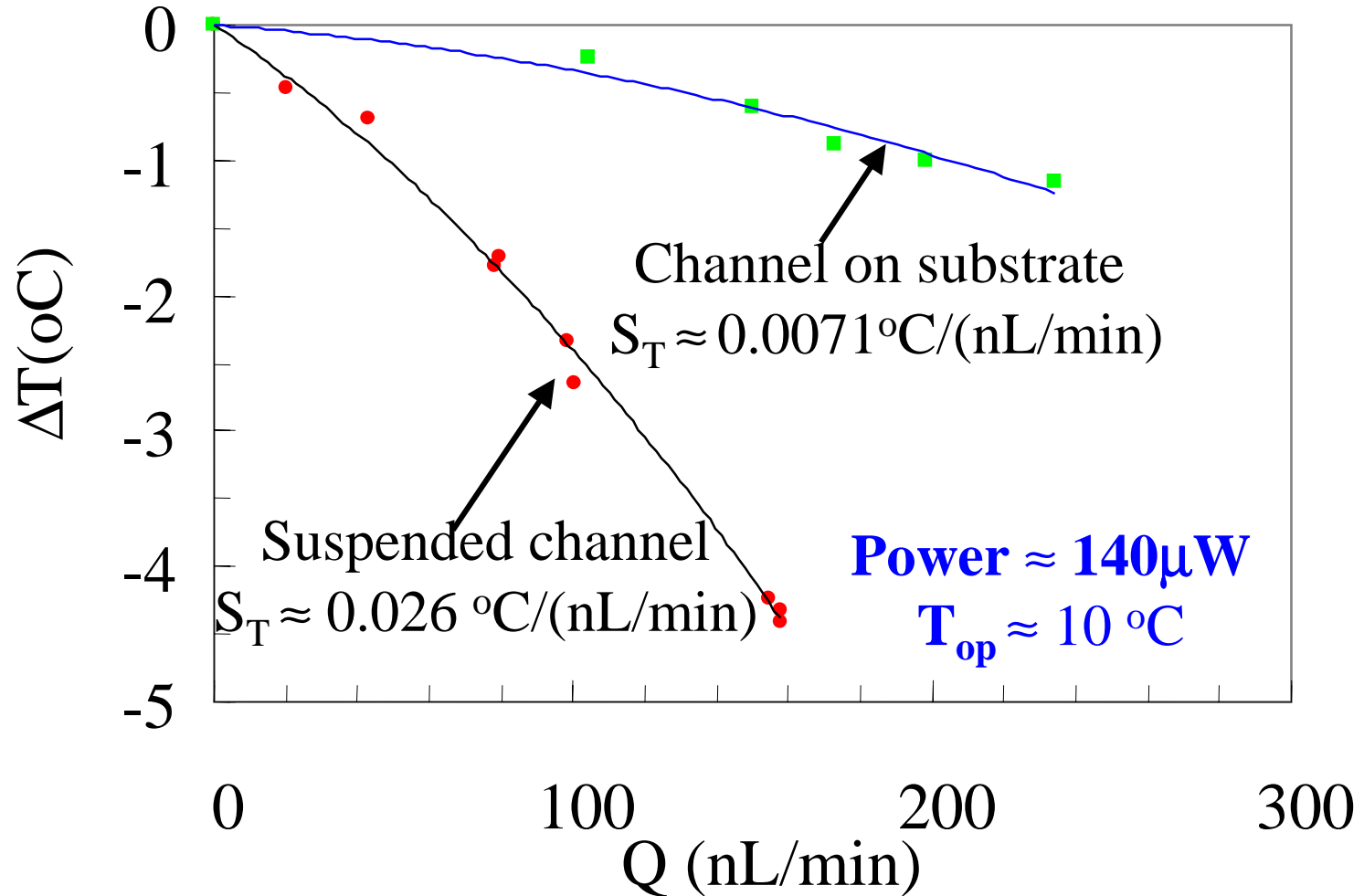


No Flow & Intermittent Power

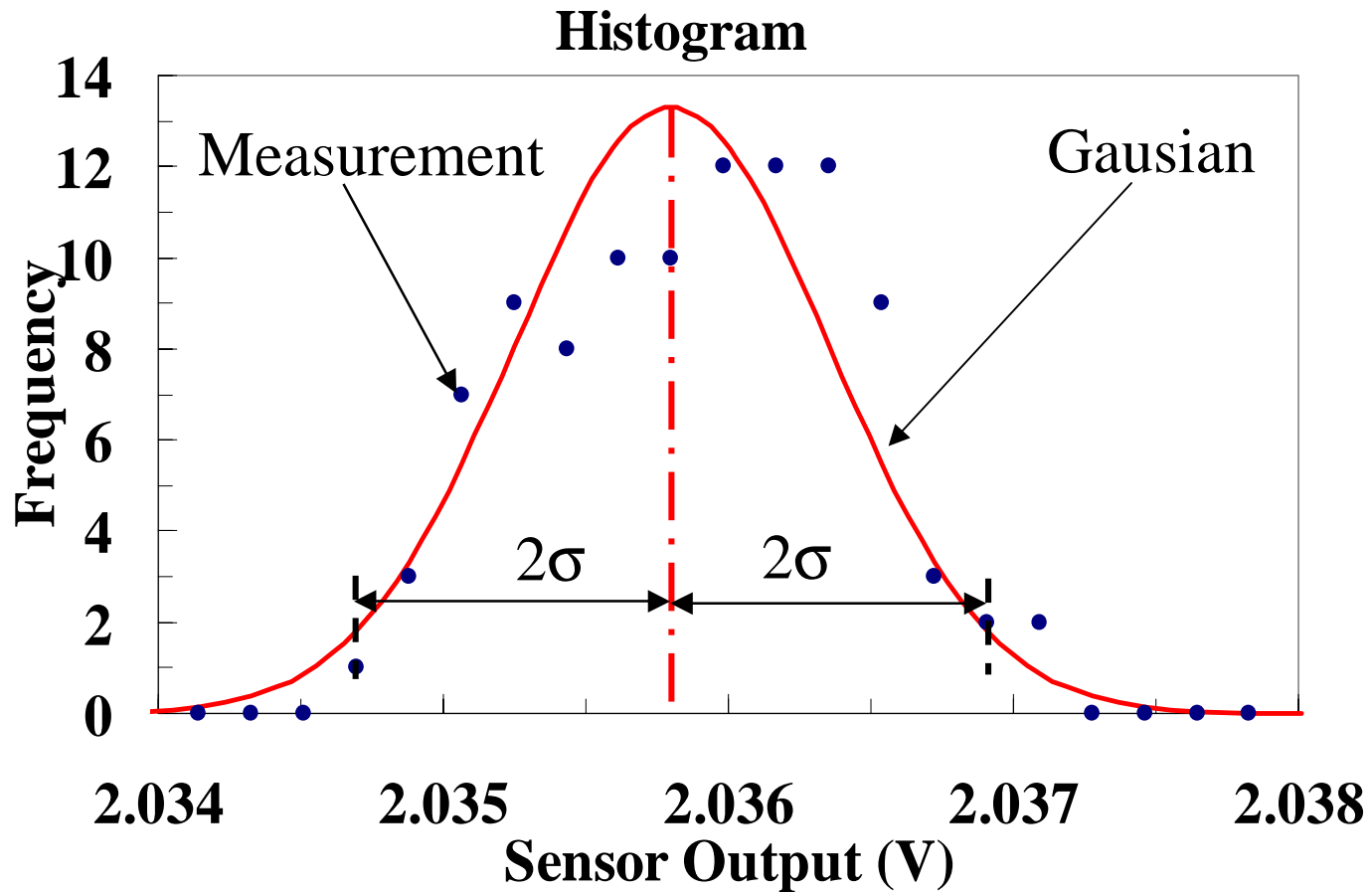
Nanoflow (nl) Sensors



Temperature Change vs. Flow Rate

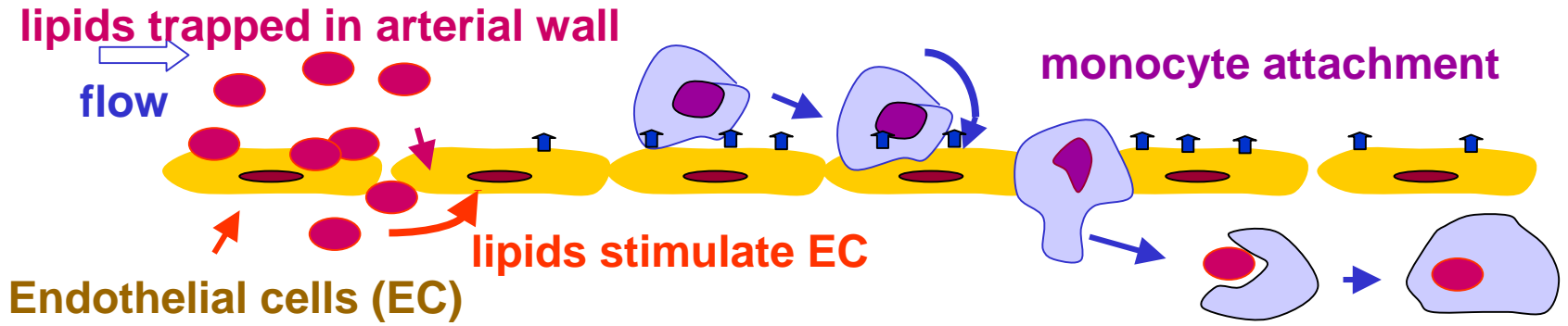


Sensor Resolution

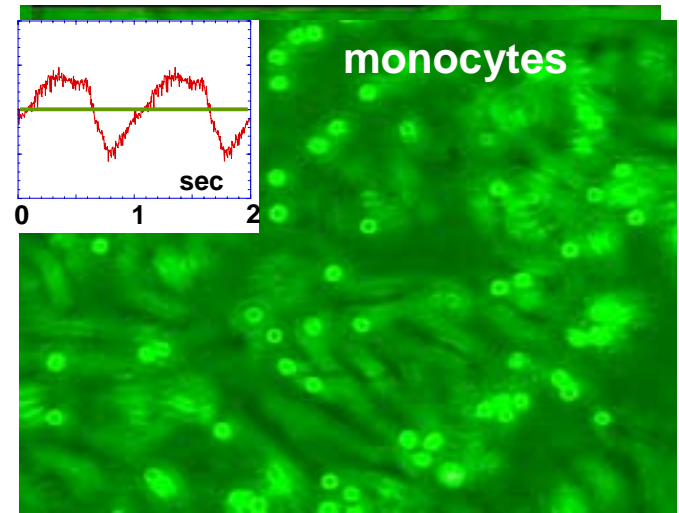
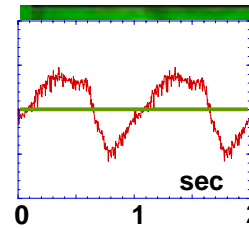
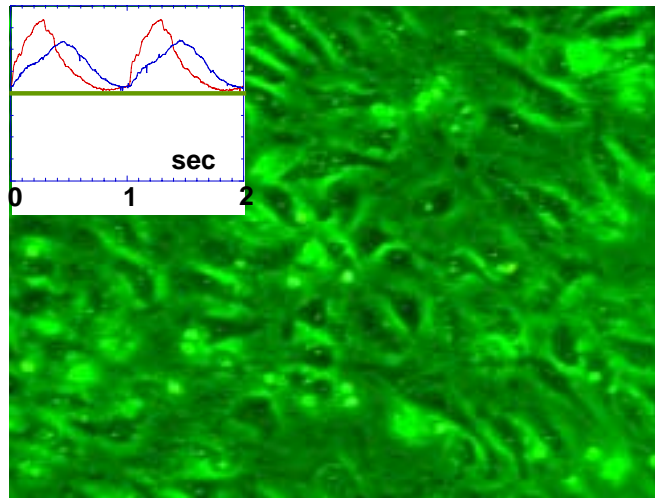
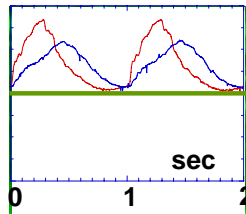
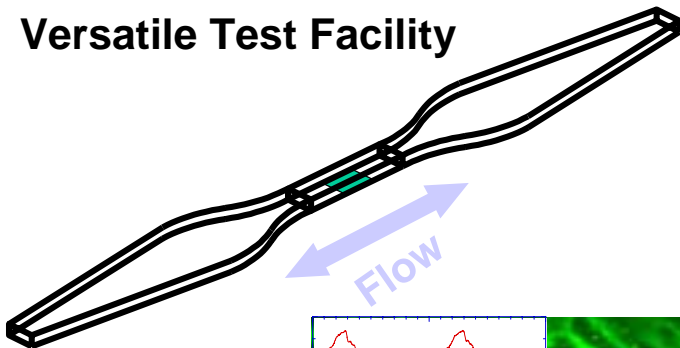


Time-averaged Resolution \approx **nL/min**

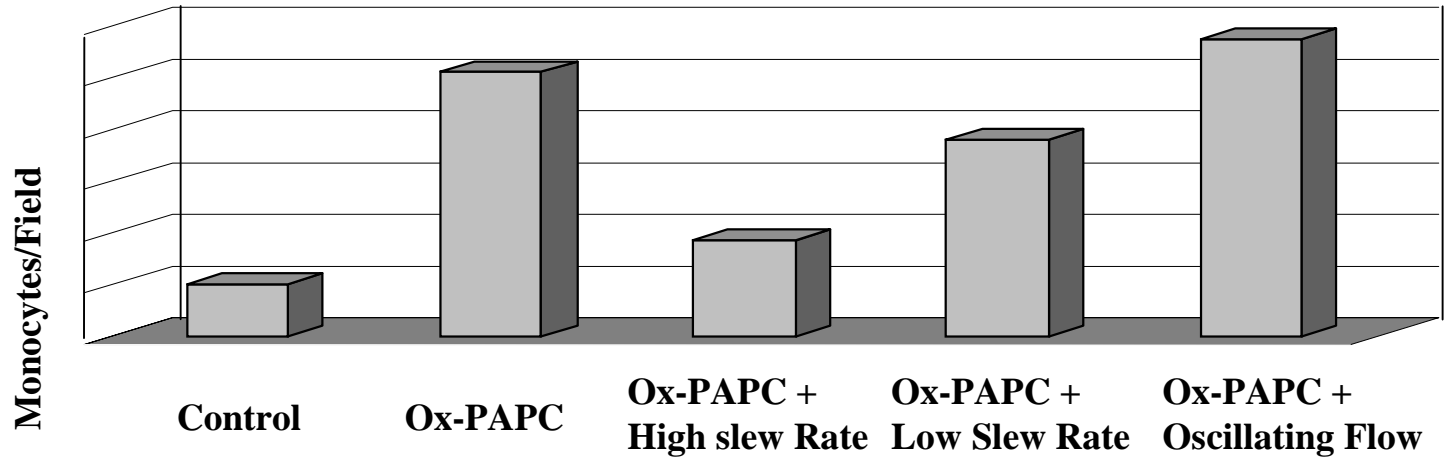
Monocyte Attachment through Molecular Recognition



Versatile Test Facility

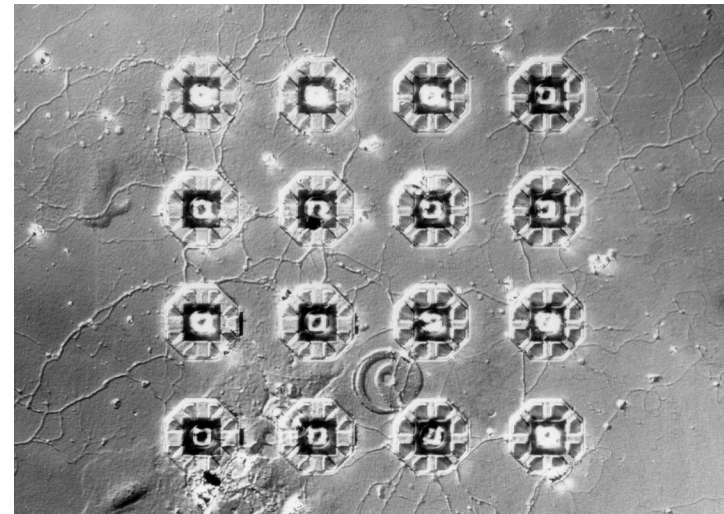
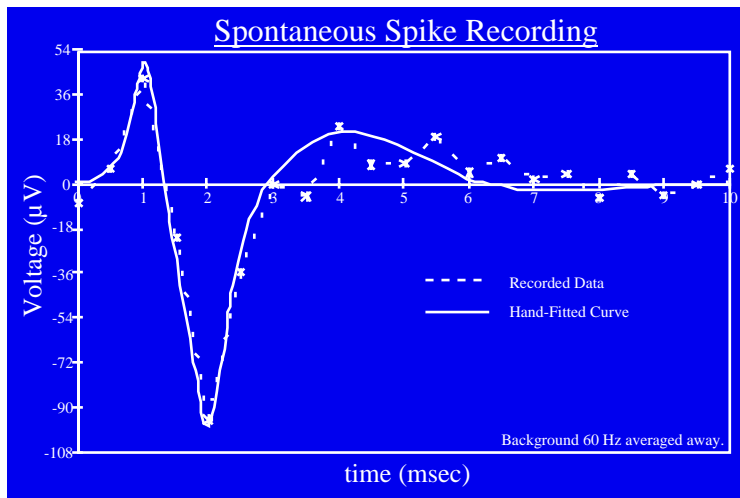
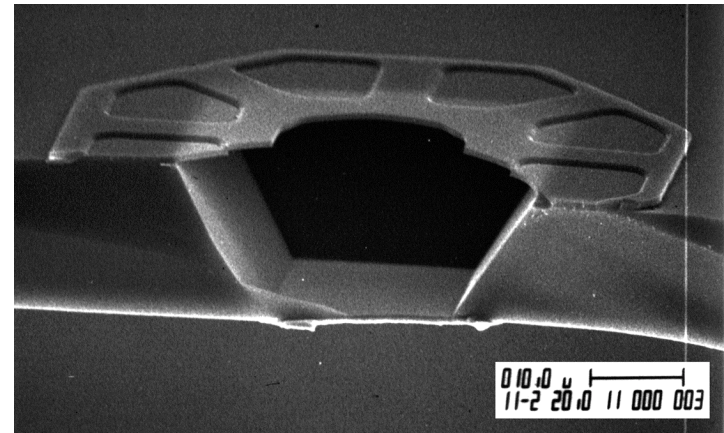
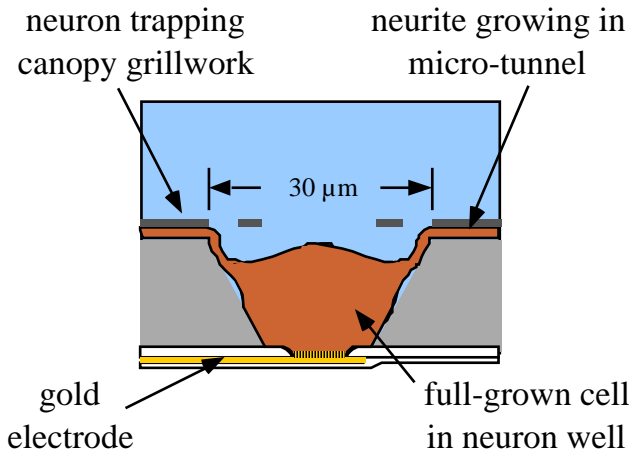


Monocyte Attachment

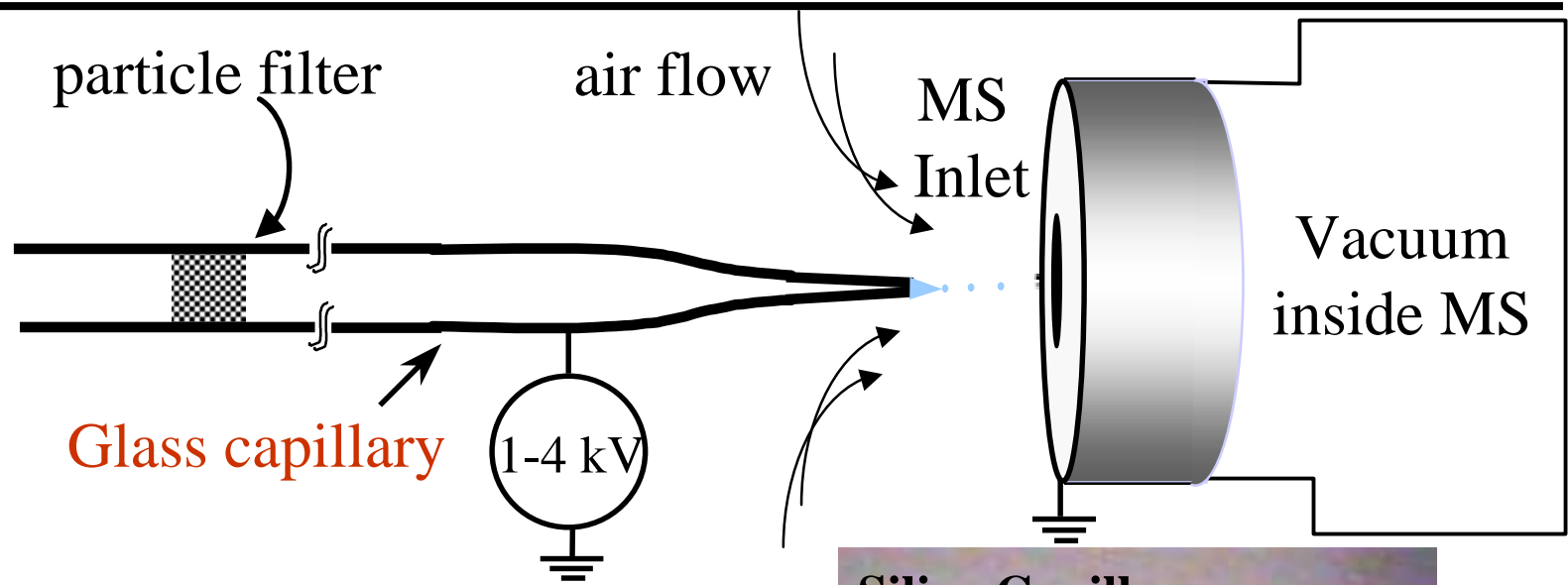


Other MEMS Applications

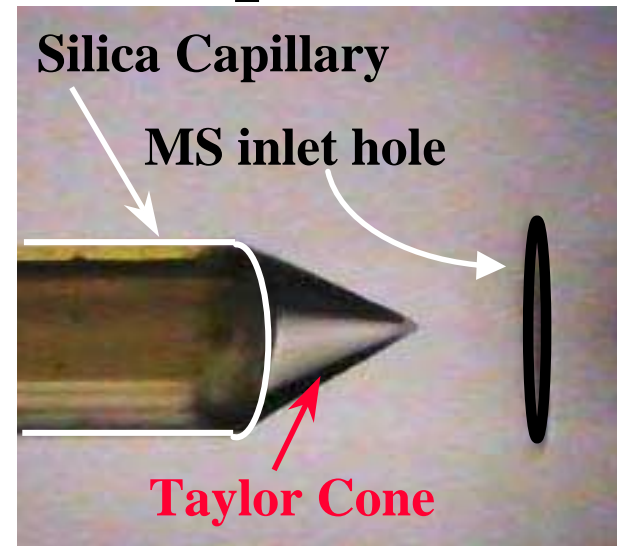
Micromachined Neurowell



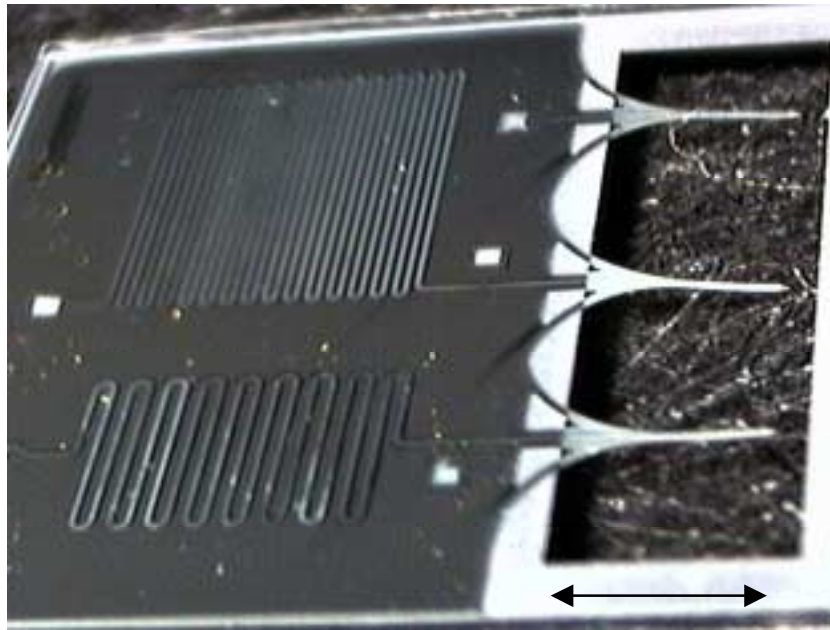
Traditional ESI for Mass Spectrometry



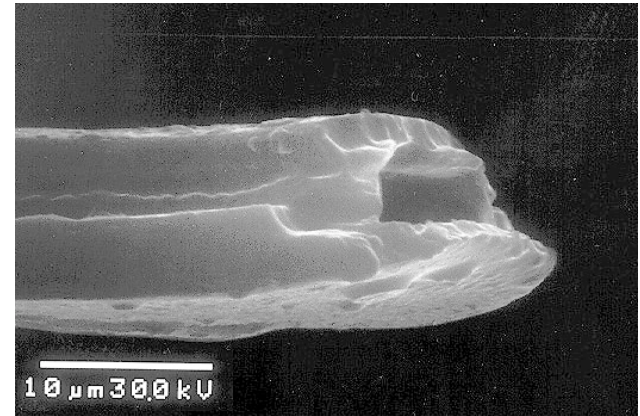
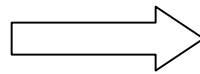
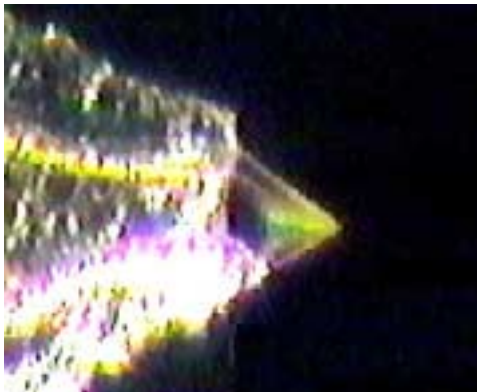
- Spray stability depends on:
 - flow rate
 - voltage
 - distance



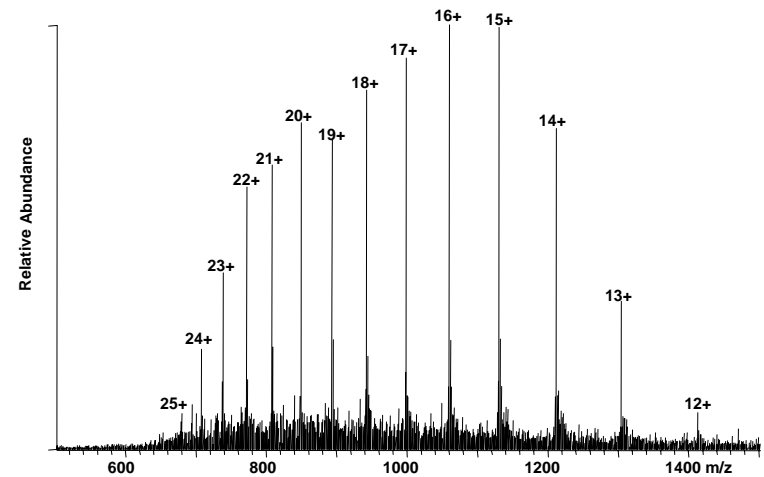
ESI Nozzle for Protein Mass Spectrometry



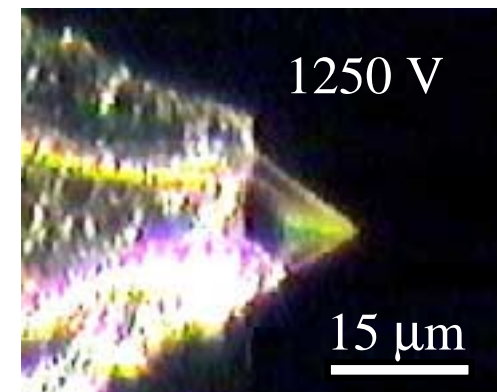
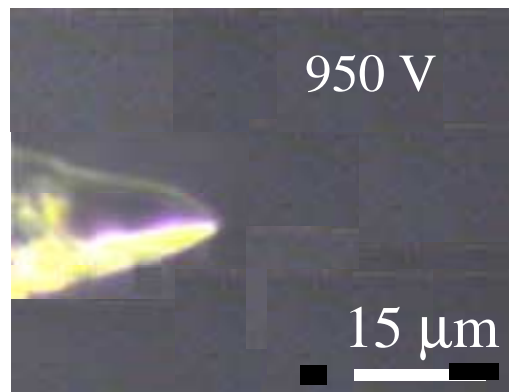
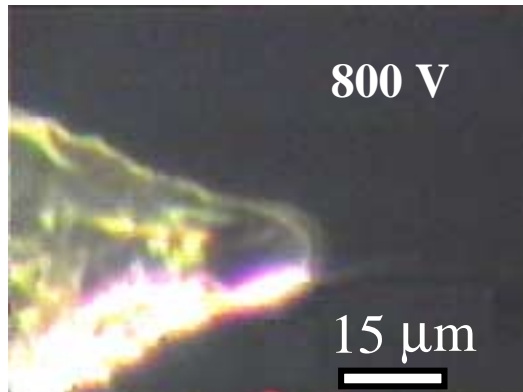
2.5 mm



SEM of Capillary Tips



Taylor Cone Formation



Solution: 1% Acetic Acid
49.5% Methanol
49.5% Water

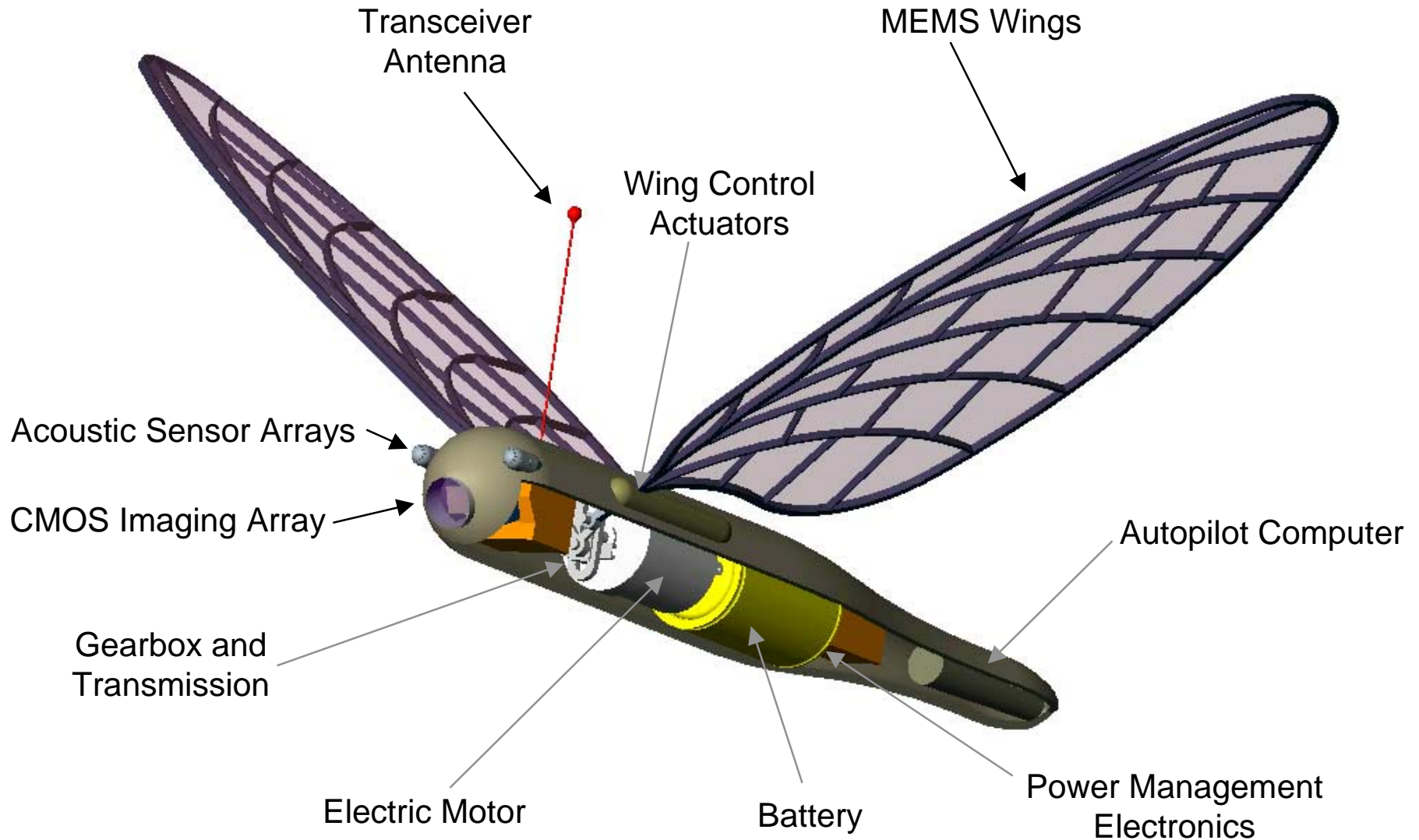
Voltage: 800 V ~ 1250 V

Distance: 500 μm from electrode



On the Microbat ...

Flying Onithopter



New MAV Design Specifications

- Weight: 12.5 g
- Wing span: 9 inch
- Flapping amp.: 65 deg
- Flapping freq.: 20 Hz
- Flight velocity: 4 m/s
- Power required: 2 W
- Power source: Battery
- Propulsion: Flapping Wings

