Smart Skin: Multi-sensory Arrays on Flexible Substrates

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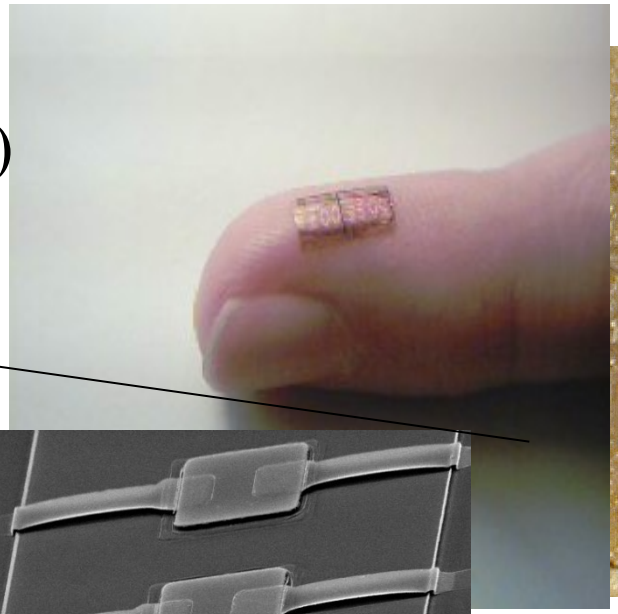
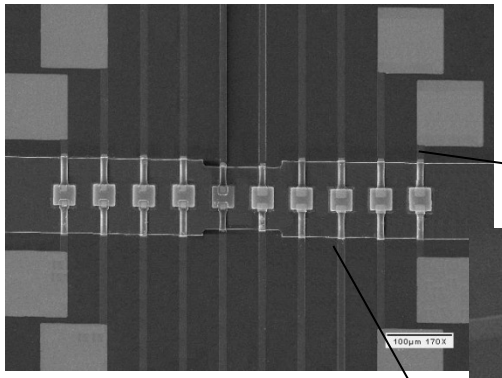
Multi-Sensory Arrays on Flexible Substrates

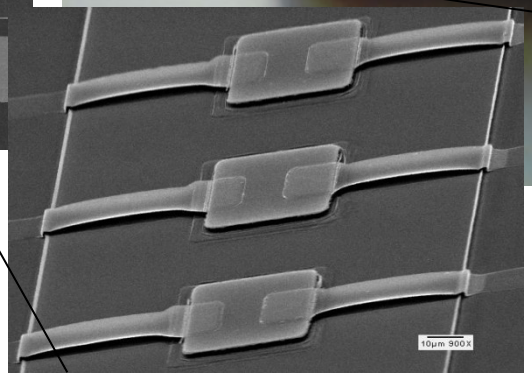
Sensing:

- Infrared radiation (temperature)
- Pressure/tactile
- Flow
- Biochemical (for future)

Two-die smart skin applied to the little finger. The flexible skin (right) contains 384 infrared microsensors.







1x10 array of infrared microbolometers (40x40 μm²) before encapsulation

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Motivation for a "Smart Skin"

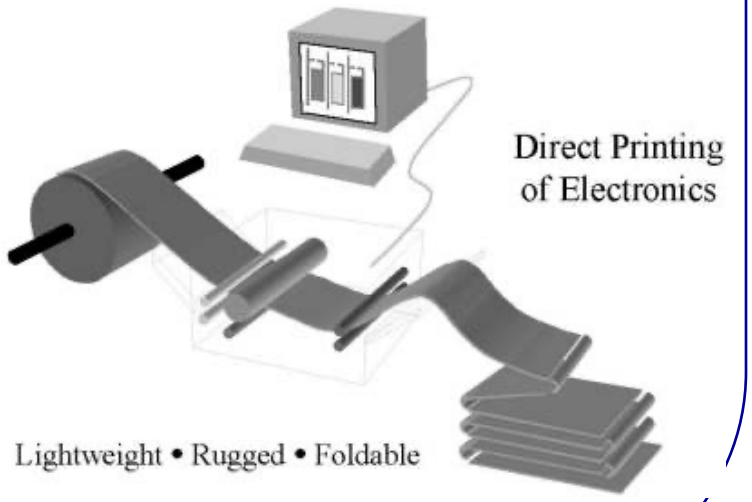
- Evolution in robotics is demanding increased perception of the environment.
- Human skin provides sensory perception of temperature, touch/pressure, and air flow.
- Goal is to develop sensors on flexible substrates that are compliant to curved surfaces.

Advantages of Flexible Substrates

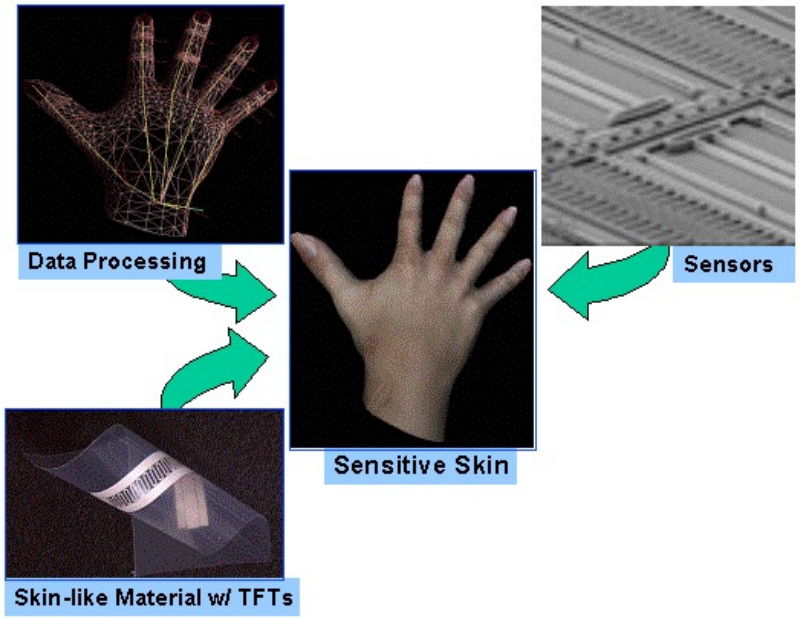
- Conform to underlying object.
- Batch fabrication potential for low cost.
- Enable applications on complex geometries.
- Multilayer construction.
- Integrated electronics in the future (TFTs).
- Expected market for electronic applications on flexible substrate, 0.8 Billion yearly*

***Electronic Trends Publications**

From S. Wagner, Princeton University



Applications: Wearable Sensors



(Motorola)

Electrotextile

(Givenchy)

Smart Glove

Soldier of the Future

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Wearable Body Monitoring Systems

Smart Bandages, University of Rochester

- Biological sensing and chemical sensing techniques with simple alerts.
- Monitoring of infants at-risk, elderly, employees working in hazardous environments.
- Multi sensing techniques integrated into fabric.

Smart Shirt, Georgia Tech: Current technology. Discrete sensors: lumpy, uncomfortable, inconvenient

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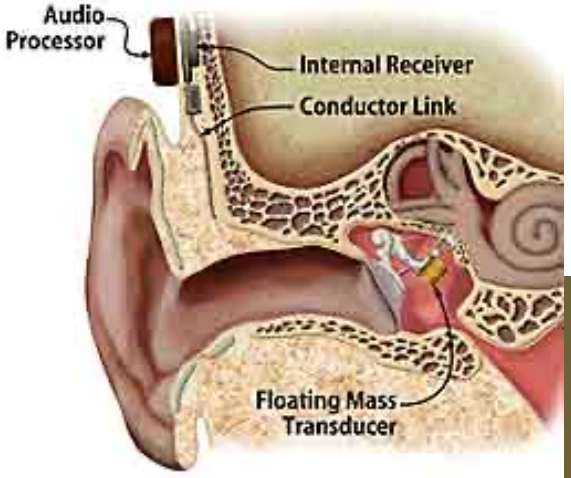
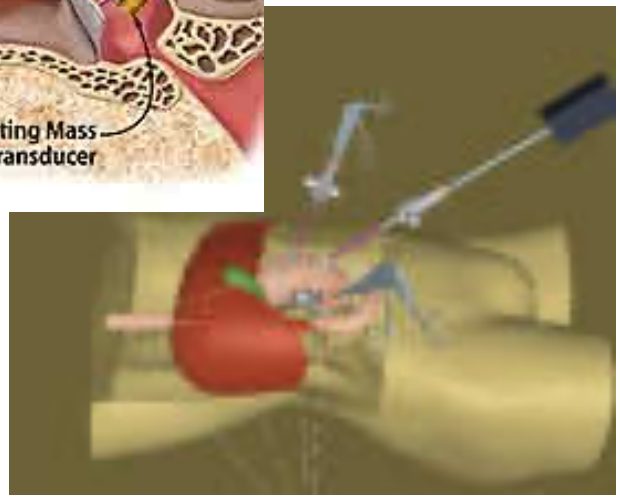
Artificial Skin for Robotics

Sensitive prosthetic devices

Roomba, the vacuuming robot, needs to “feel”.

Cochlear implants for full spectrum hearing restoration





Minimally invasive surgery with instruments that “feel”.

Artificial Skin for Robotics

Lockheed Martin MicroSTAR

- Micro Air Vehicles
- Microbats
- Multi sensing techniques integrated into autonomous flying objects..

- Integration of microactuators and microsensors on a flexible substrate

MAV – CalTech/UCLA

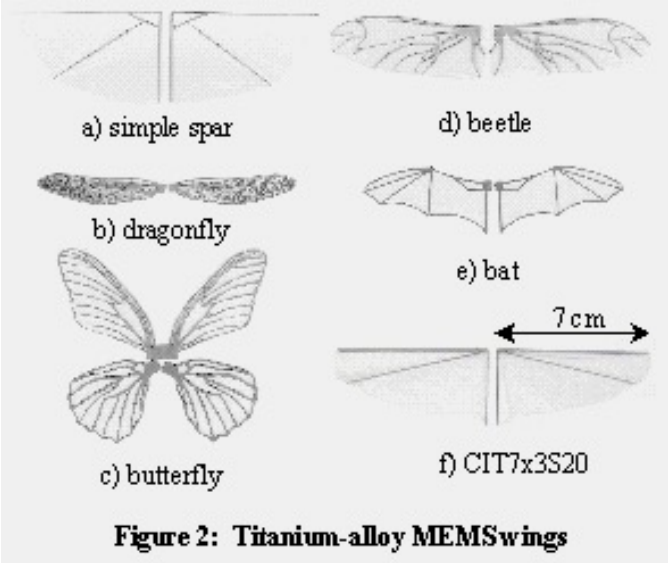


Figure 2: Titanium-alloy MEMSwings

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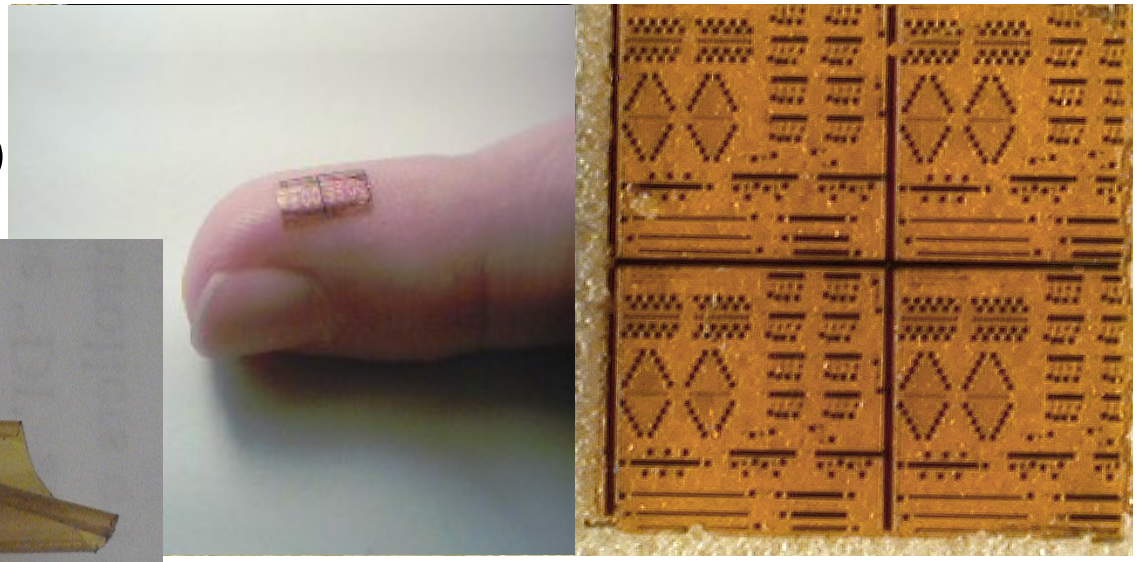

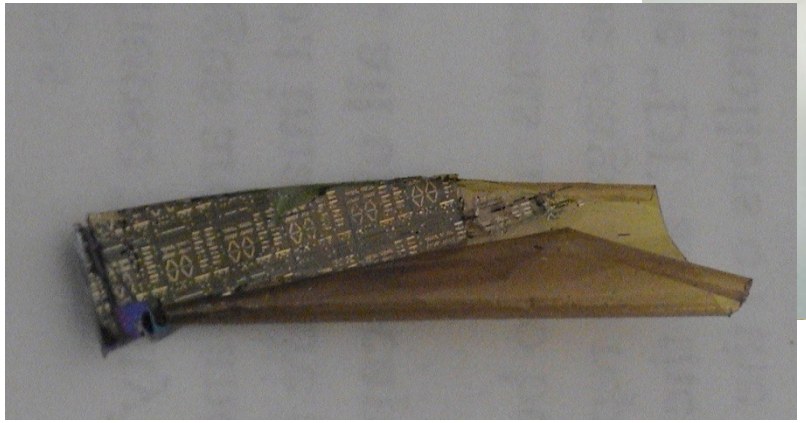

A piece of "Smart Skin" developed at NanoFab-UTA. There are over 1,000 sensors on this piece of skin.

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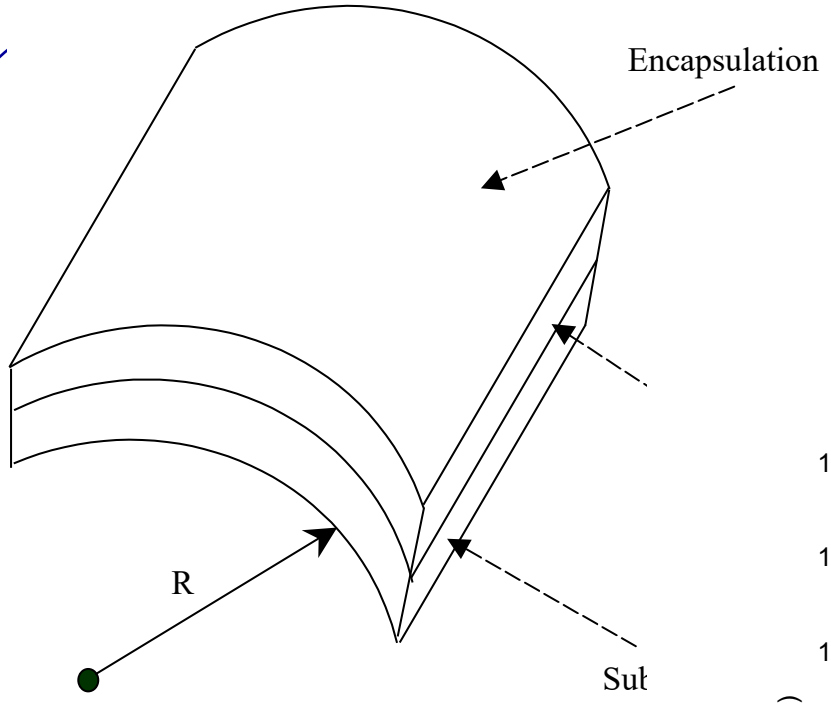
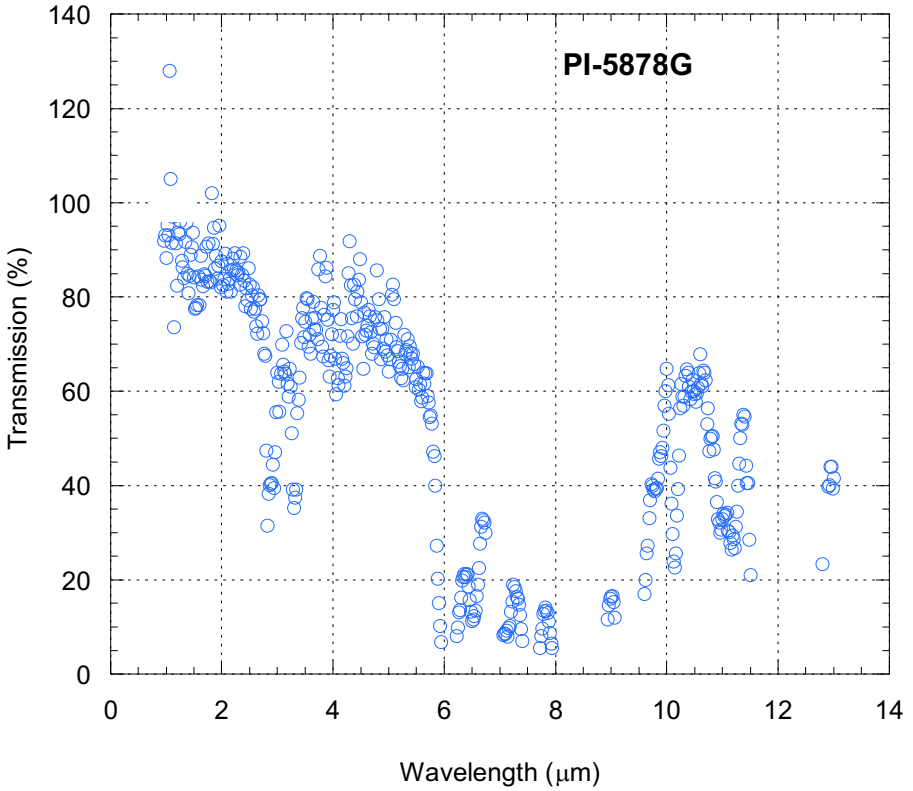
Self-Packaging



- Encapsulate microbolometers in a vacuum cavity on the no strain plane with polyimide superstrate.
- Integrate flow sensors and pressure/strain sensors.



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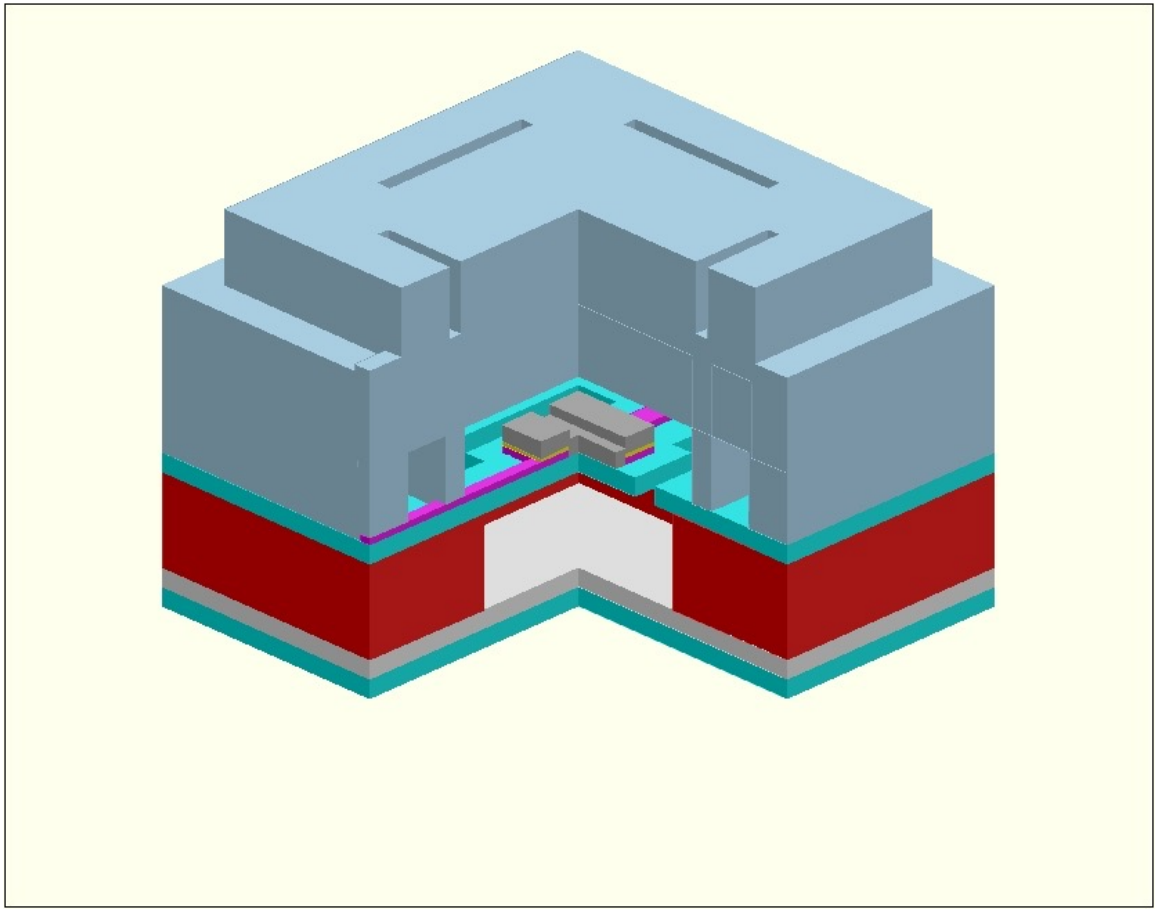
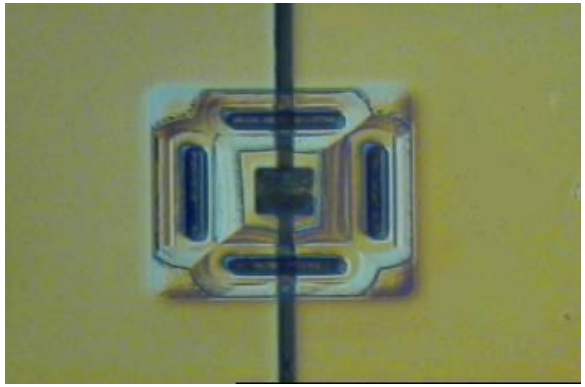
Fabrication

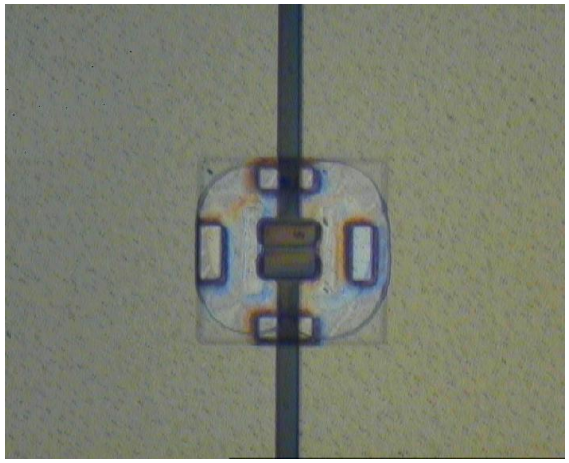
(Sealed vacuum cavity)



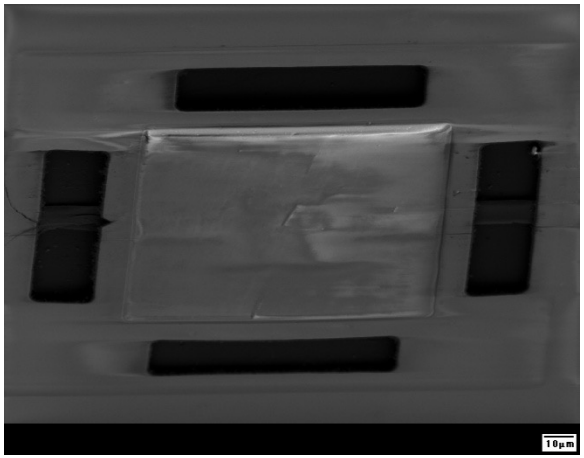
Fabrication of encapsulated devices



Partially micromachined device

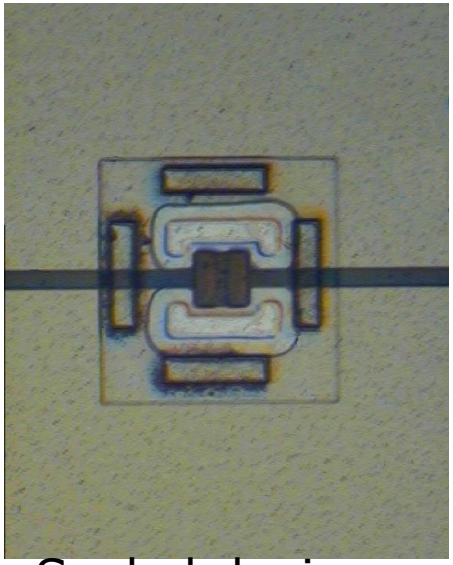


Fully micromachined device

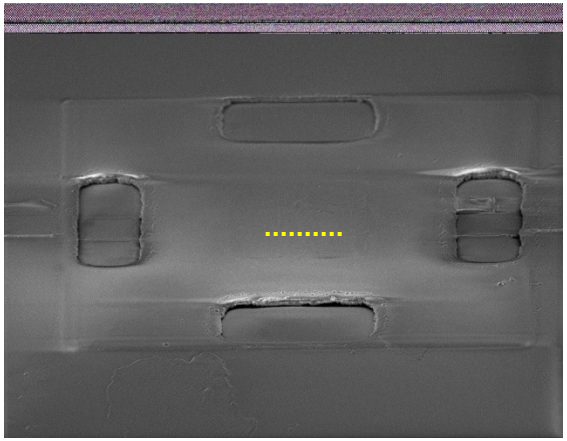


SEM graph of an unsealed micromachined device

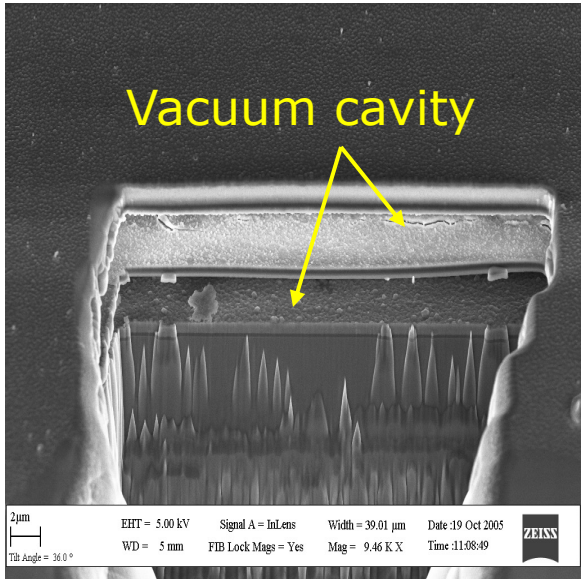
Fabrication of encapsulated devices



Sealed device



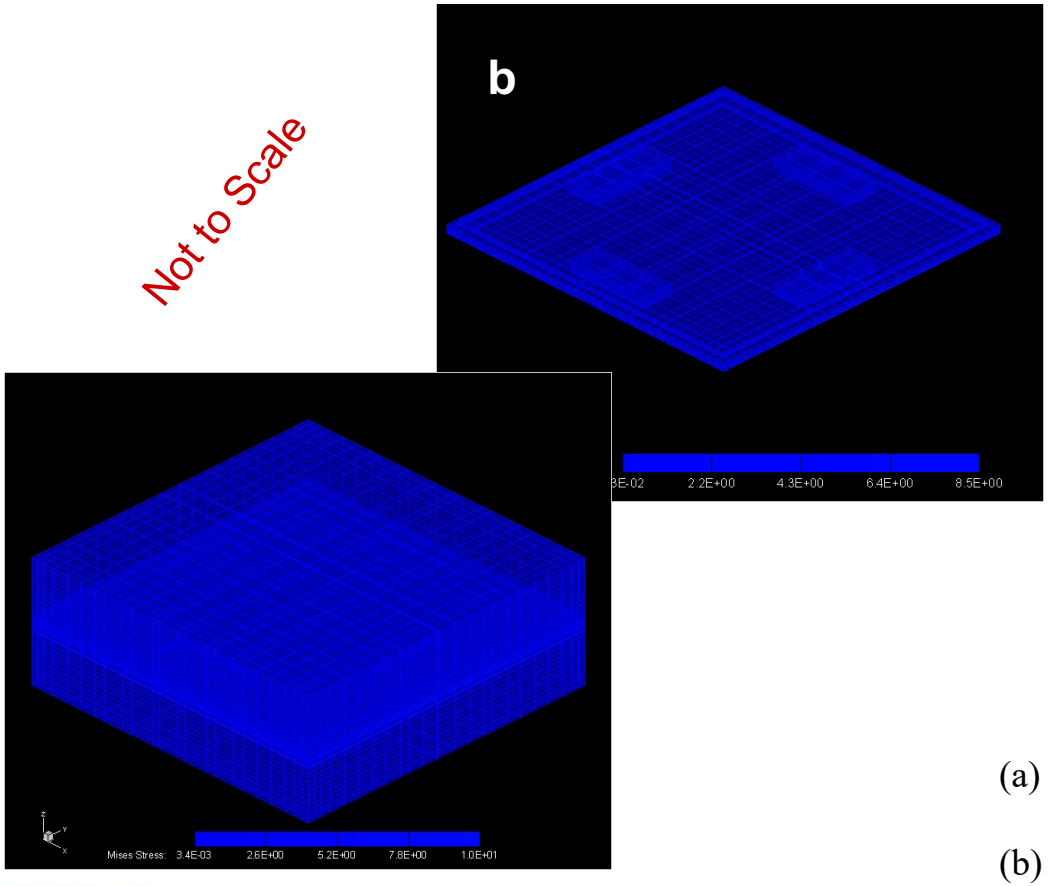
SEM graph of sealed device

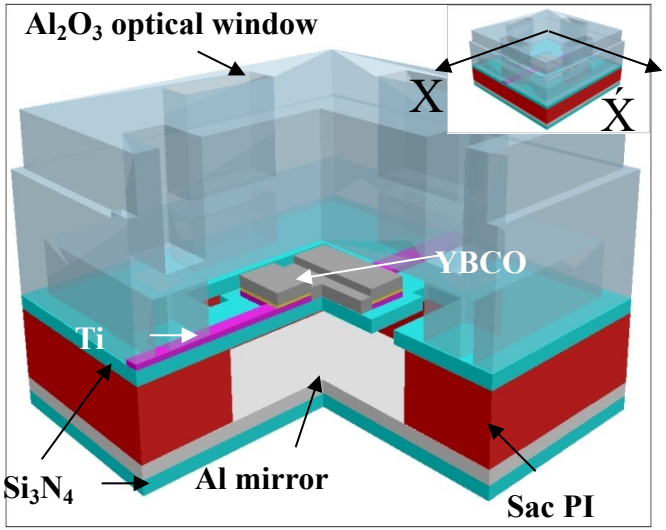


SEM graph of cross section of vacuum cavity

Modeling of Induced Stress

Von Mises stresses produced in Al_2O_3 layer when bent over a circular radius. Al_2O_3 has a yield stress of 2944 MPa





Computer generated model of a microbolometer encapsulated in a vacuum cavity. Polyimide substrate and superstrate are not shown.

(a) Von Mises stresses induced by bending the sample. (Motion is not shown)

(b) Only the Al_2O_3 shown

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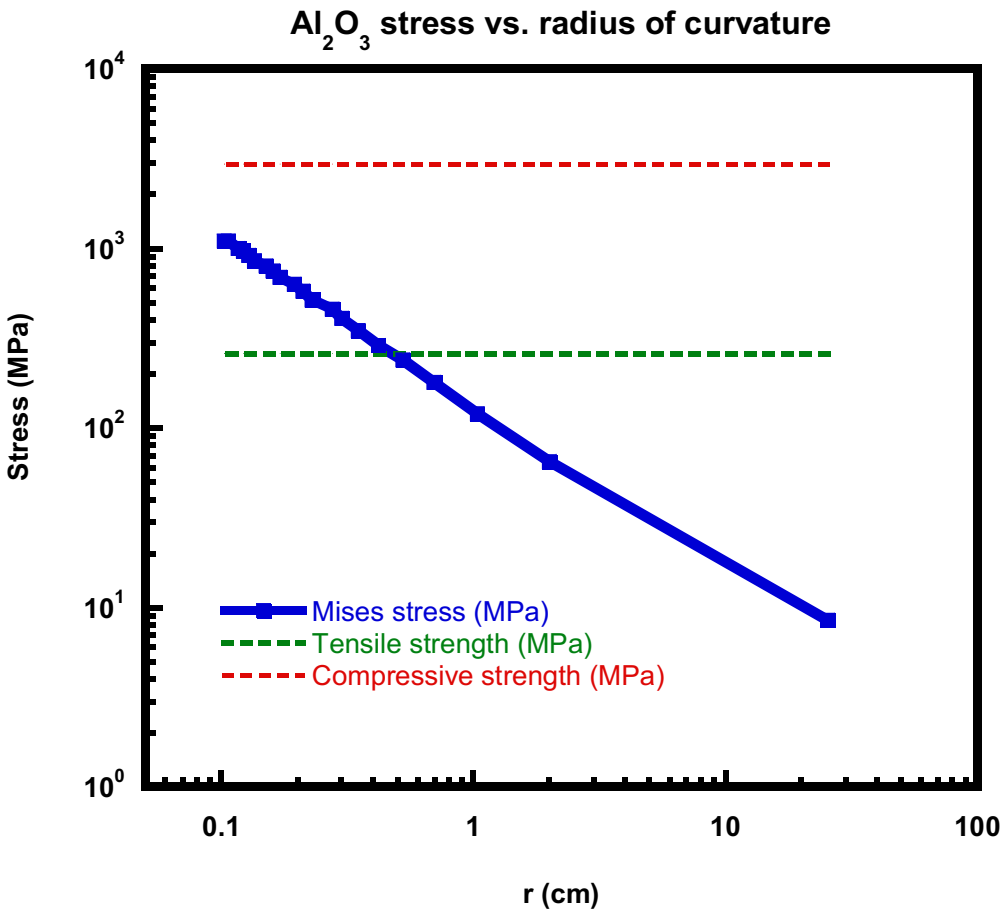
Al_2O_3 Stress Analysis



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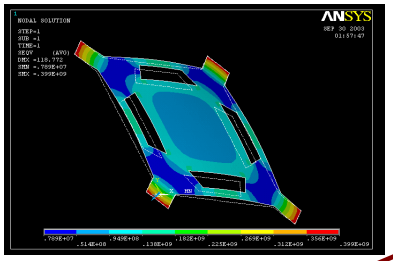
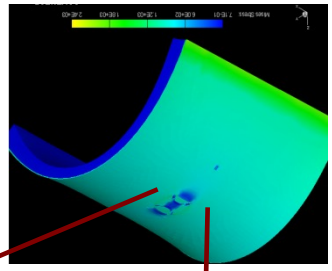
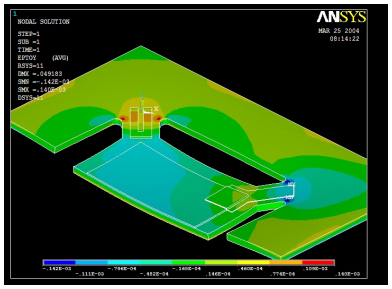
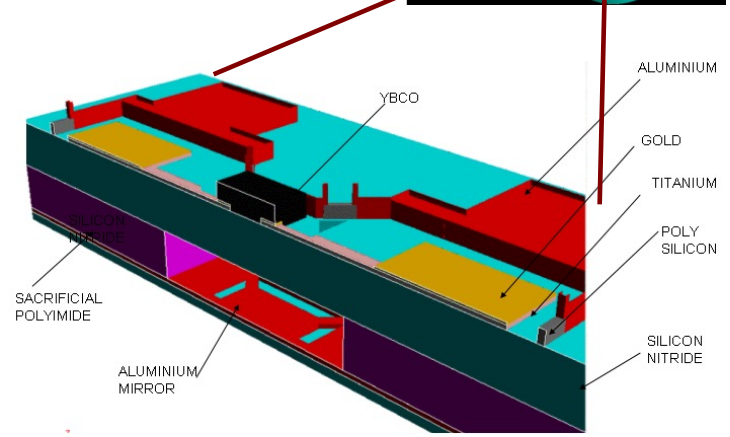
UTA's Tactile Sensors on Flexible Substrates









- **Top Right:** ANSYS® simulation of response of a pressure sensor to 50kPa normal pressure.
- **Top Middle:** An ANSYS® simulation of an integrated thermal/tactile sensor on a polyimide. The colors indicate the stress due to the applied pressure.
- **Top Left:** An ANSYS simulation of a loaded integrated sensor.
- **Left:** Cross-section of a single integrated thermal/pressure sensor. The Smart CPR system will be an array of these pixels.

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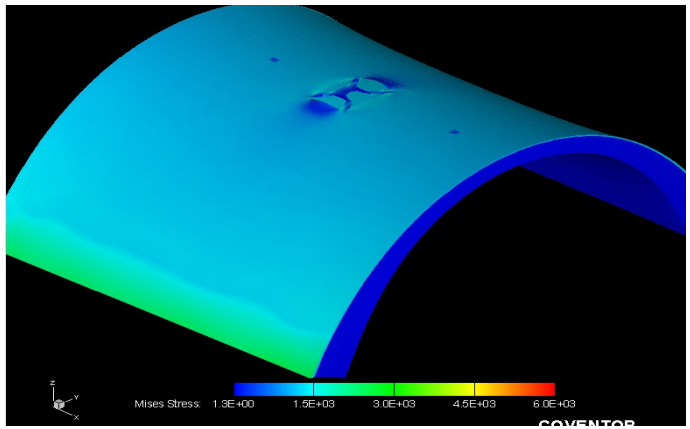
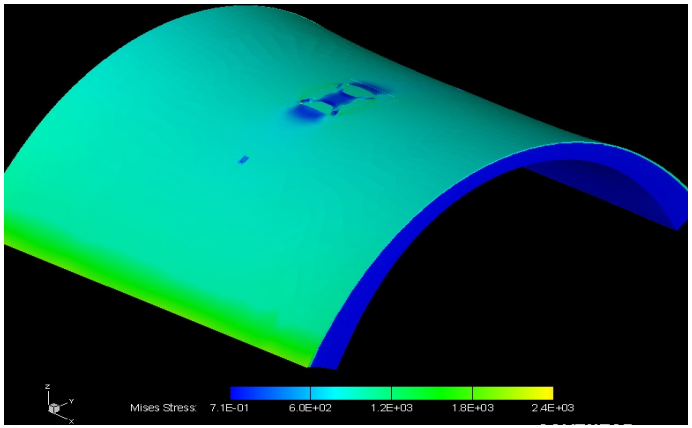
Sample Skin Bending-Different Sensor Orientations

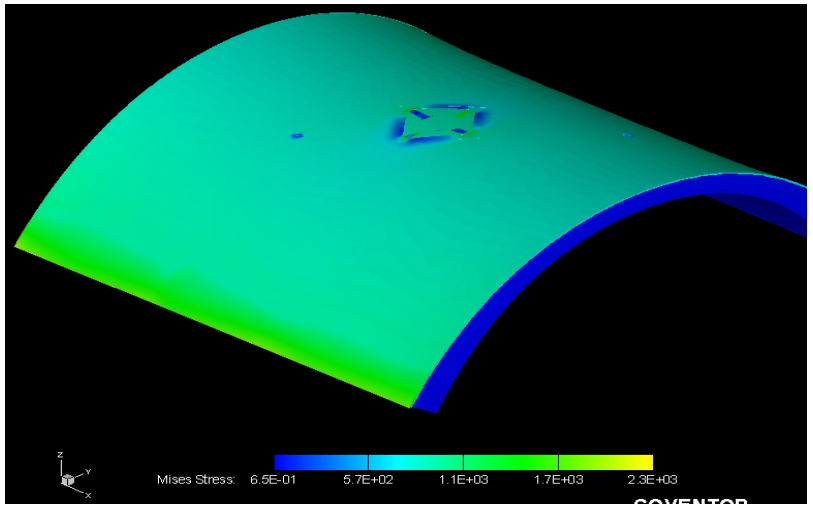
0^0



90^0



45^0



Different orientations of DV-UL-P for skin bending
0^0 , 45^0 and 90^0

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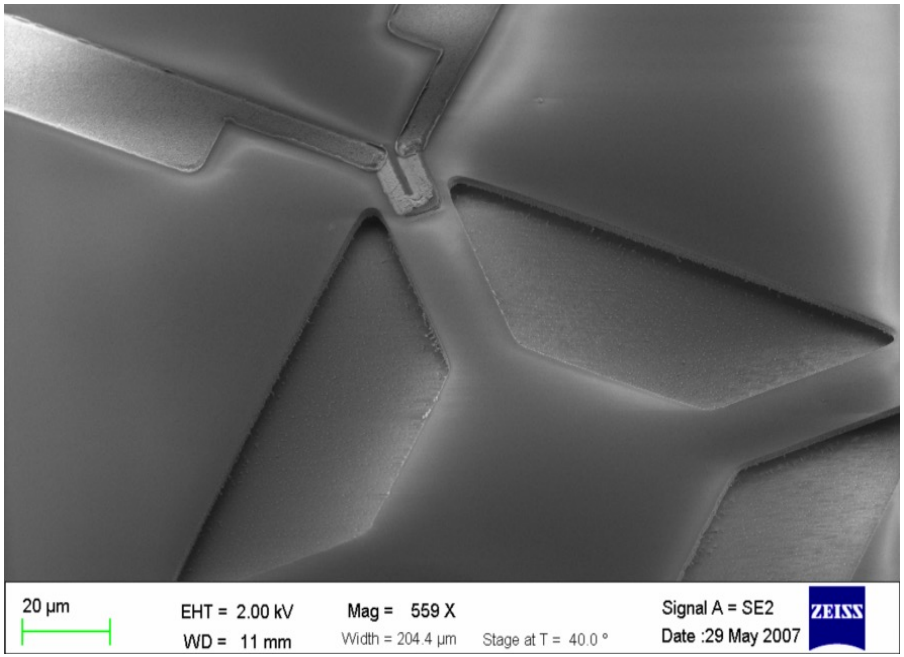
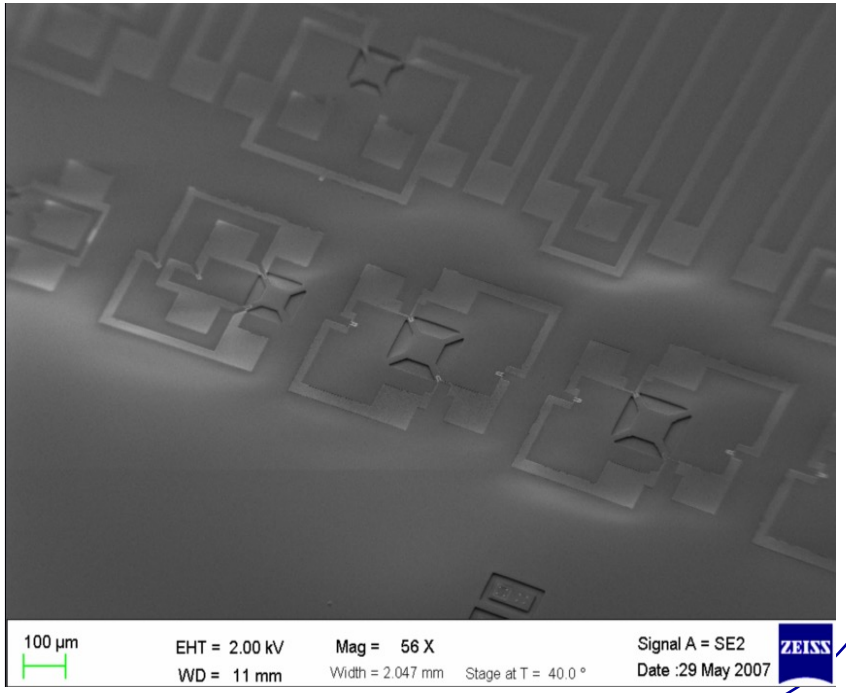
Pressure Sensors on Flexible Substrates



We are in the process of developing pressure/tactile sensors on flexible substrates.



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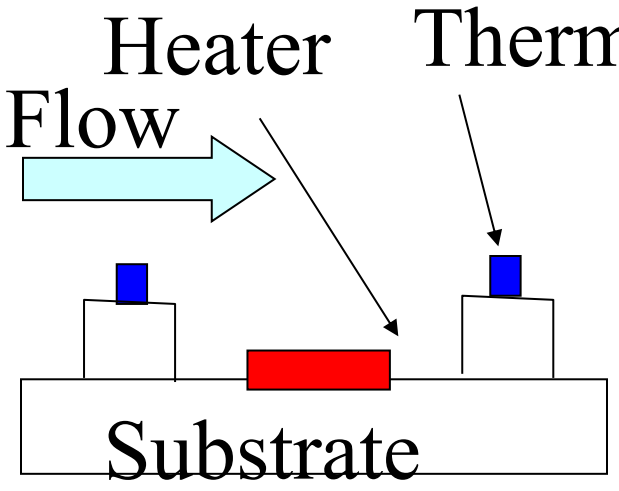
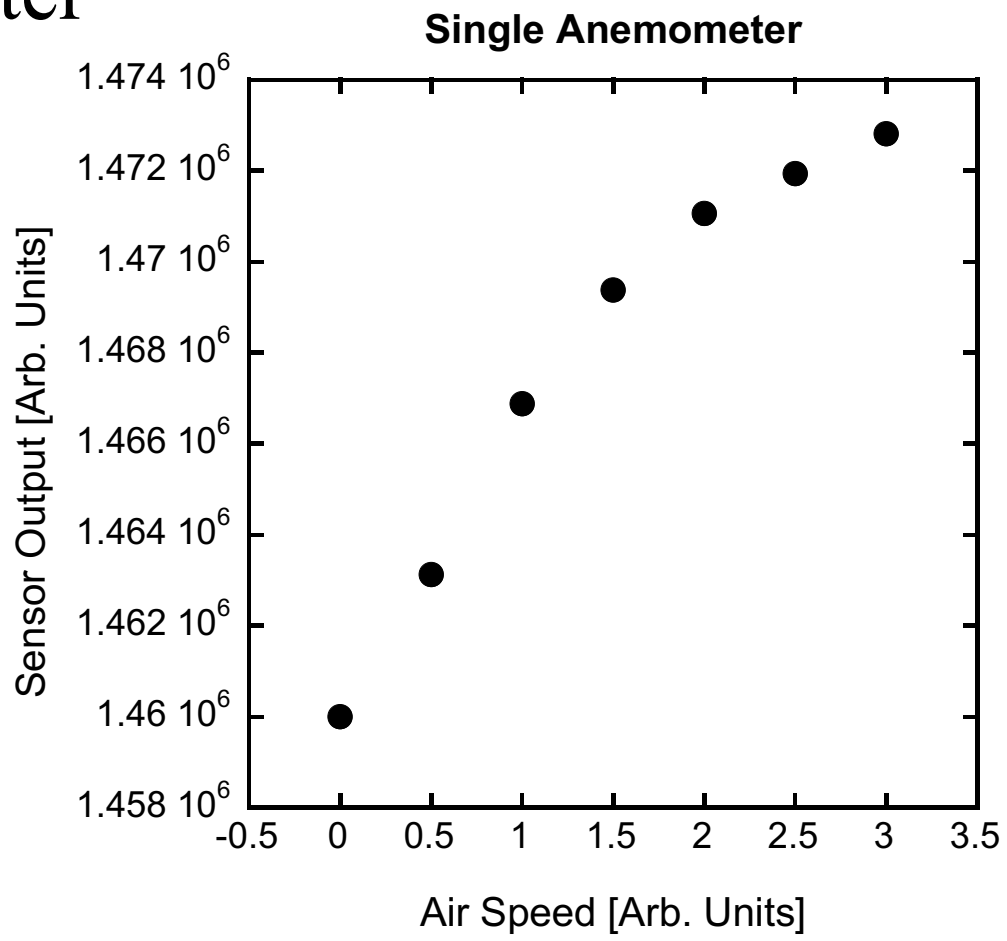
Thermal Flow Sensors





King's Law: For self-heating anemometer with fixed ΔT and the heater power P_h is given by

$$\Delta T_{12} = T_2 - T_1 = Q_m c_m / P_h$$

Q_m is the mass flow rate, c_m is the thermal capacity