Lab on CMOS Microsystems

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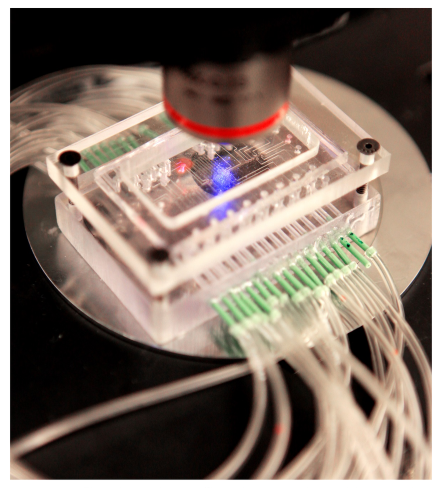
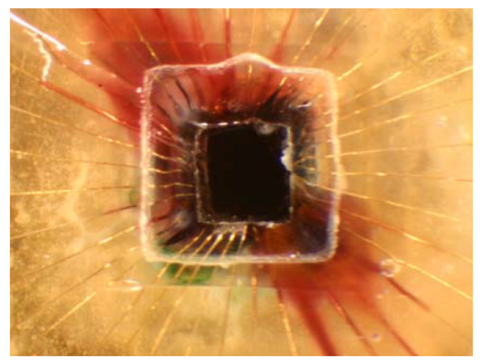
THIRTY YEARS OF SYSTEMS RESEARCH EXCELLENCE

INSTITUTE FOR SYSTEMS RESEARCH
A. JAMES CLARK SCHOOL OF ENGINEERING

Lab on a chip ≡ Chip in lab


Purdue News Service, Andrew Hancock



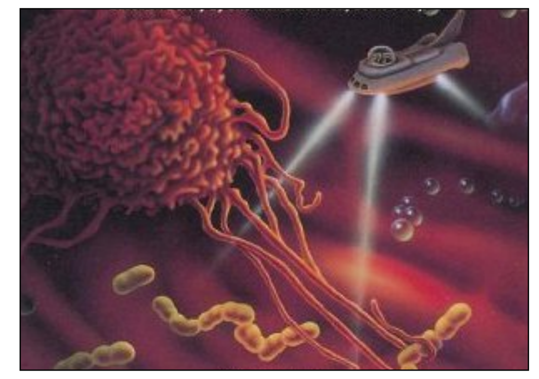
Today's lab on a chip systems are passive chips with sensing accomplished using traditional laboratory equipment.

Goal: To reduce cost and power and improve portability of sensing systems by integrating Complementary Metal Oxide Semiconductor (CMOS) chips for sensing and processing in Lab on CMOS microsystems

Technical Challenges:

- Size incompatibility between CMOS and microfluidics
- Signal shorting and coupling through wet interface
- Electrochemical effects
- Need for additional microfabrication of structures such as electrodes

Lab on a chip + CMOS ≡ Lab on CMOS


Issac Asimov's Fantastic Voyage (1966)

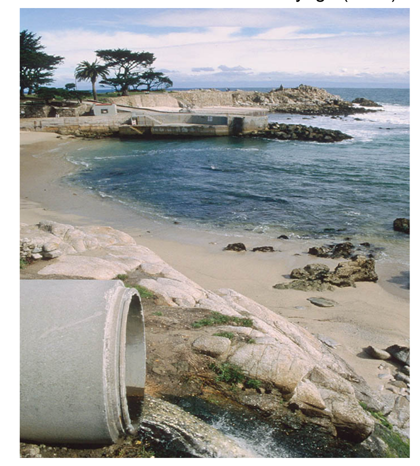
Move towards autonomous, portable, and handheld systems with CMOS serving as both instrumentation and computation mechanisms.
Examples: **Nose on a Chip** and **Cell viability monitoring**


http://commons.wikimedia.org/wiki/File:FarmersMarketProduce.jpg

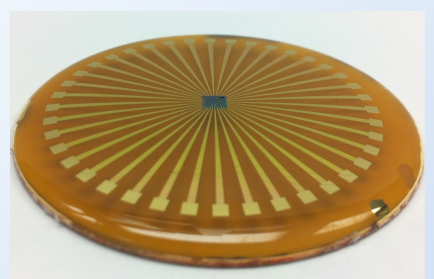
Future Applications:

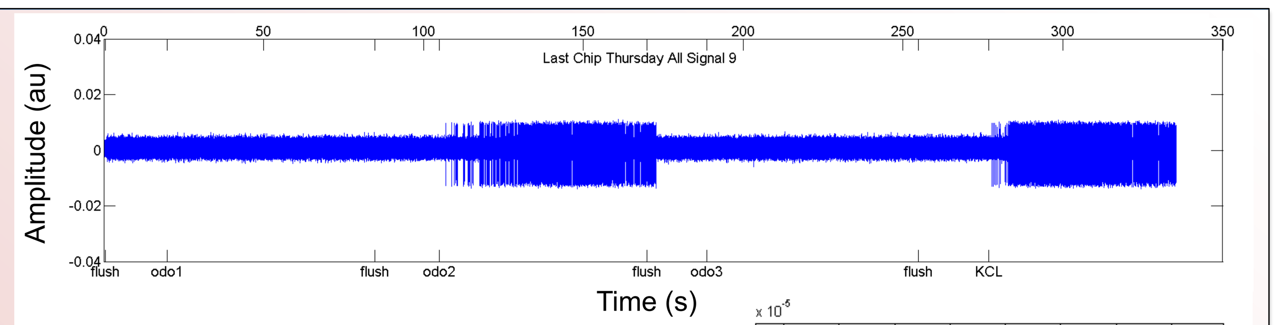
- Industrial: Food safety, fraud detection, quality monitoring
- Medical screening and diagnosis
- Defense/Security: IED/landmine detection, entry-port inspections, biometrics, search and rescue
- Environmental Monitoring: Water quality testing, pollution detection

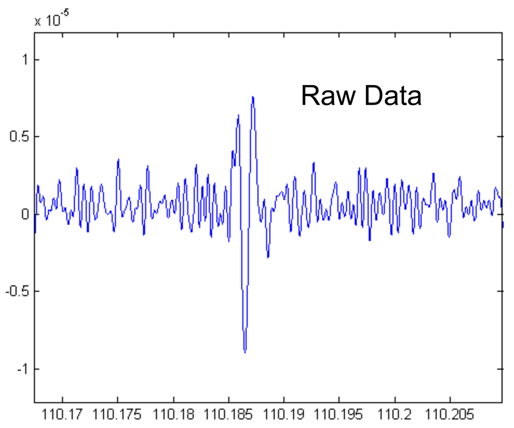

http://www.biocruiser.com/wp-content/uploads/2012/07/IMG_5958.jpg


http://montereybay.noaa.gov/photos/impact/urbanrunoff.jpg

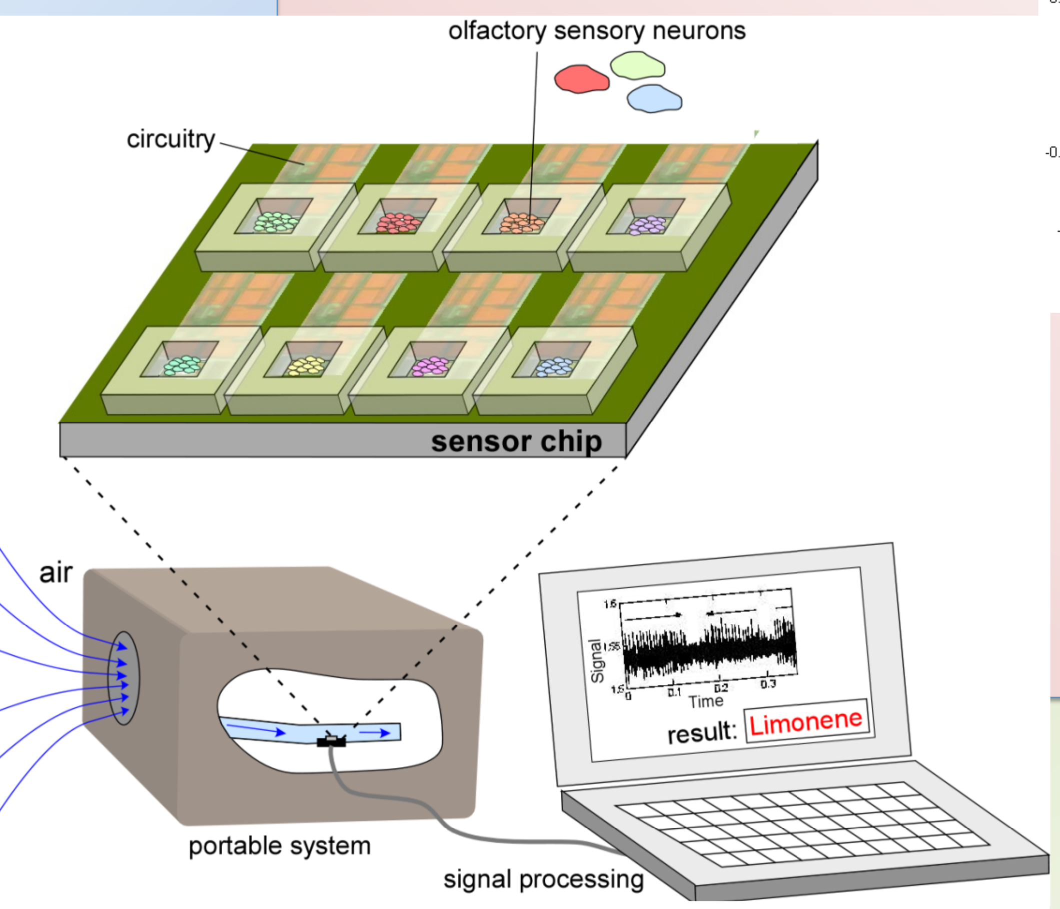
Packaging
Chip embedded into epoxy handle wafer. Standard microfabrication techniques to pattern and passivate metal traces. Other structures fabricated as needed. Electrodes coated with conjugated polymer to reduce impedance.

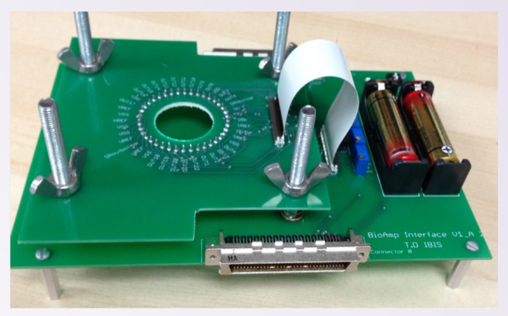






Data acquisition interface
Printed circuit board designed to connect chip pins to data acquisition system.





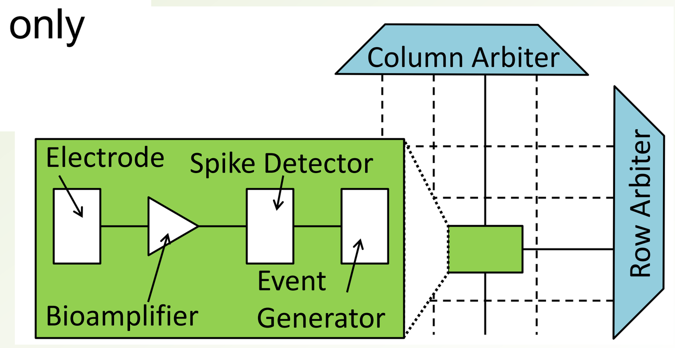
The motherboard contains headers for connection to the data acquisition system along with power and biasing circuitry for the chip. The daughterboard contains spring-loaded connections to the packaged chip.

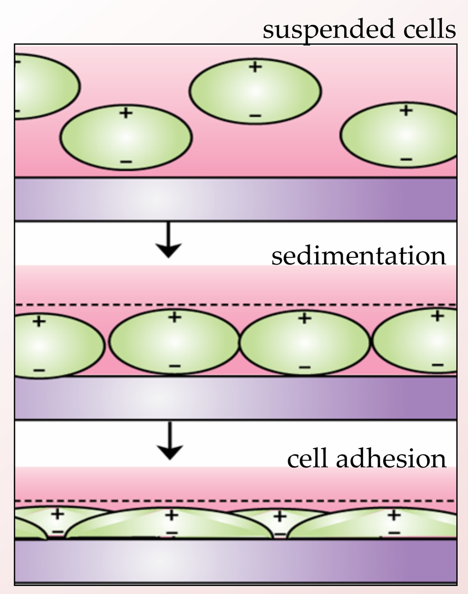
System test results
System tests show specificity to odors. This channel responds to odor 2 and positive control.

Nose on a Chip

Existing olfactory sensors are limited in scope and sensitivity. Highly trained animals remain the only viable option for high-value sensing.

Signal processing
Active micro-electrode array comprises grid of pixels, each with bioamplifier, spike detector, and asynchronous readout.



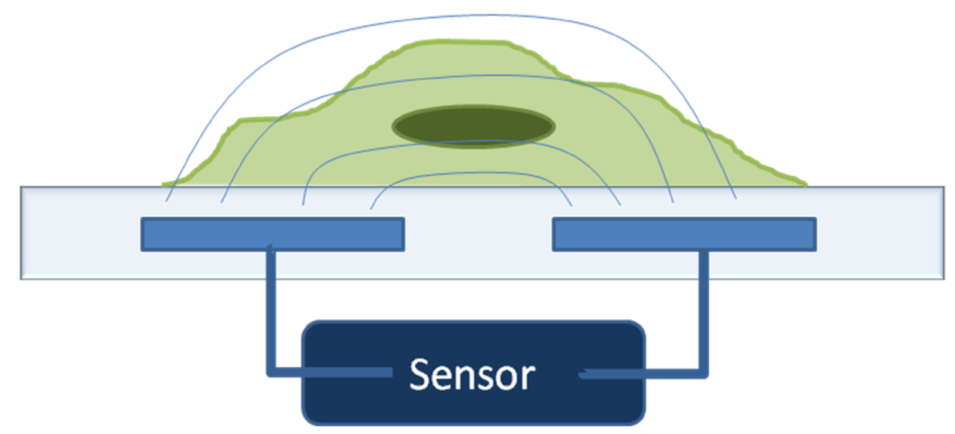


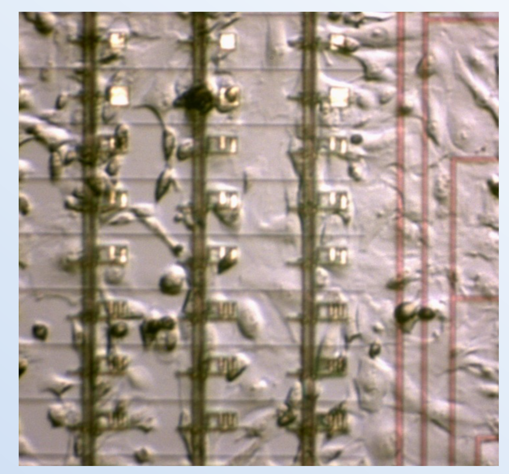
Cell adhesion
Most cultured cells are anchorage-dependent and require a solid substrate for growth. Suspended cells first sediment at the sensor surface before adhesion and proliferation.

Capacitance sensing of cell viability
Cells cultured on sensing electrodes act as a variable dielectric layer. This allows the sensor to be used as an indicator of cell health and the presence of toxins.

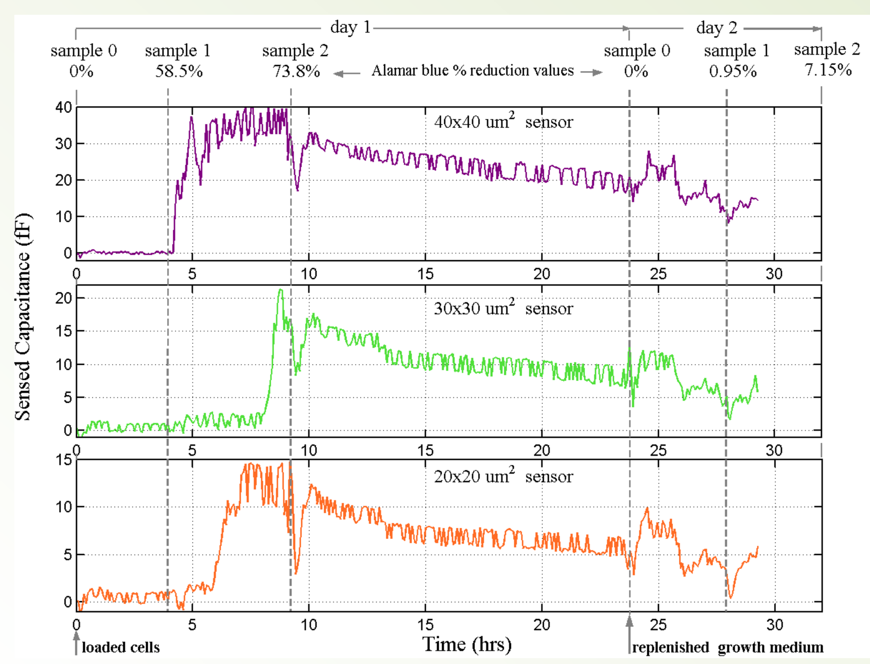
- Unhealthy cells adhere weakly: low capacitance
- Healthy cells adhere strongly: high capacitance

Cell viability monitoring

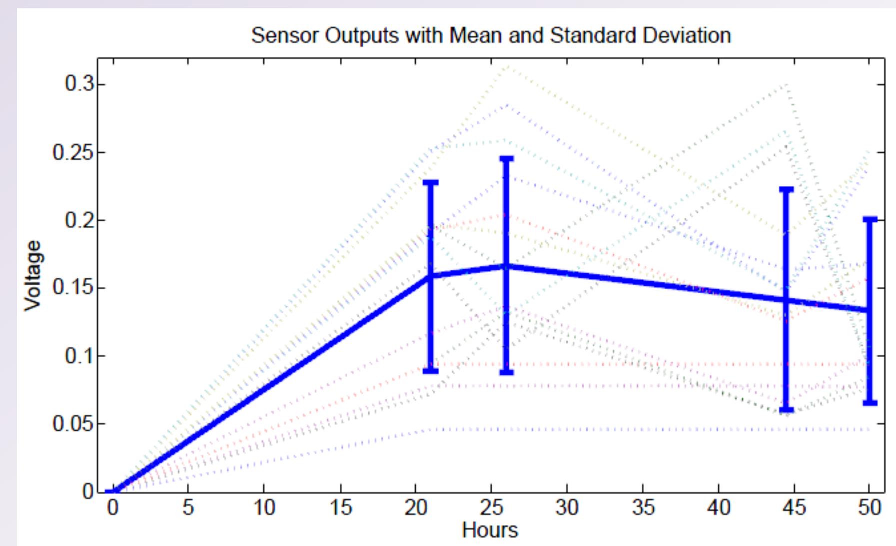




Validation of cell viability and adhesion measurements
Capacitance traces show initial sedimentation/adhesion. Traces are correlated with an independent metabolic assay.



Nanoparticle toxicity investigation
Nanoparticles added at 24 hours resulting in cells slowly separating from surface as they become unhealthy.



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Integrated Biomorphic Information Systems Lab
The Laboratory for Microtechnologies