Lab on CMOS Microsystems

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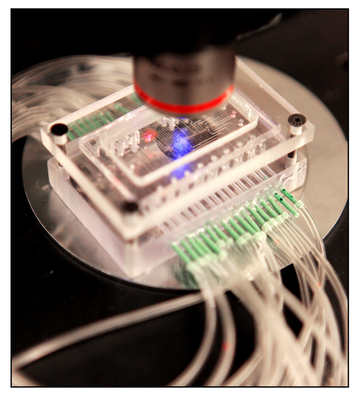
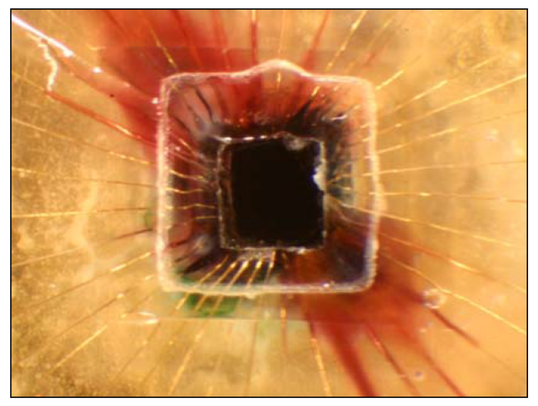
Lab on a chip ≡ Chip in lab

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


Purdue News Service, Andrew Hancock



Lab on a chip + CMOS ≡ Lab on CMOS

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**

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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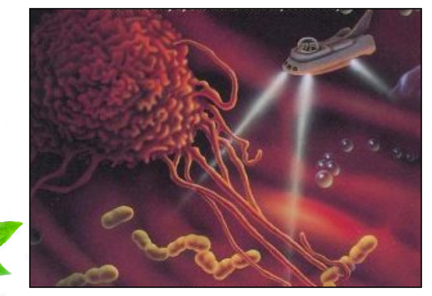
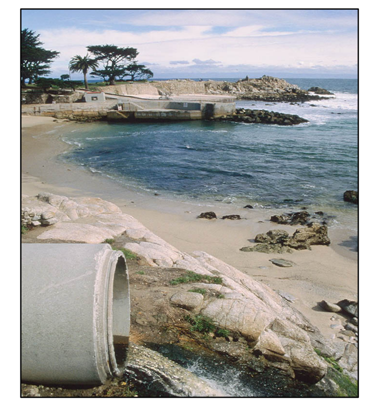
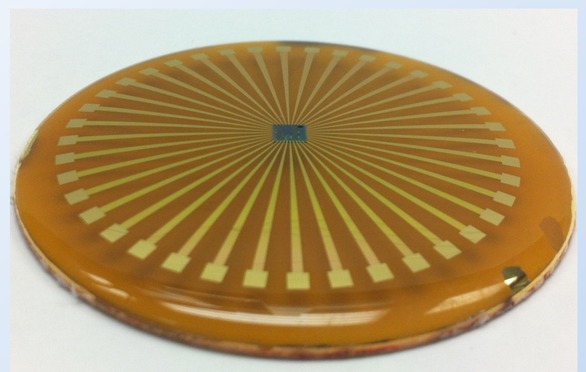

Issac Asimov's Fantastic Voyage (1966)

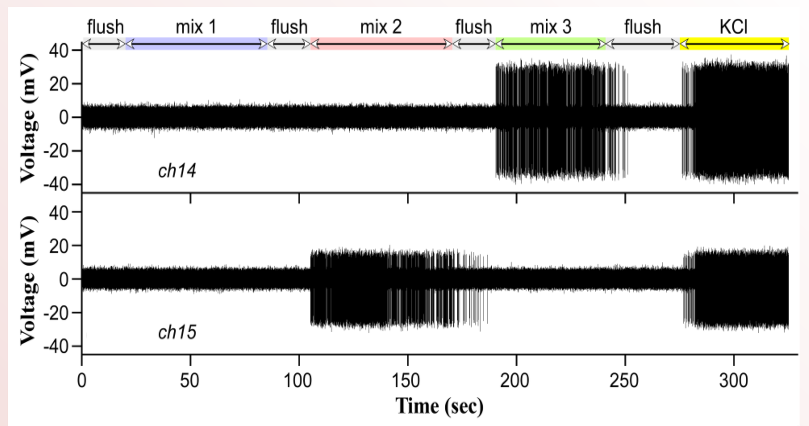
BioCruiser

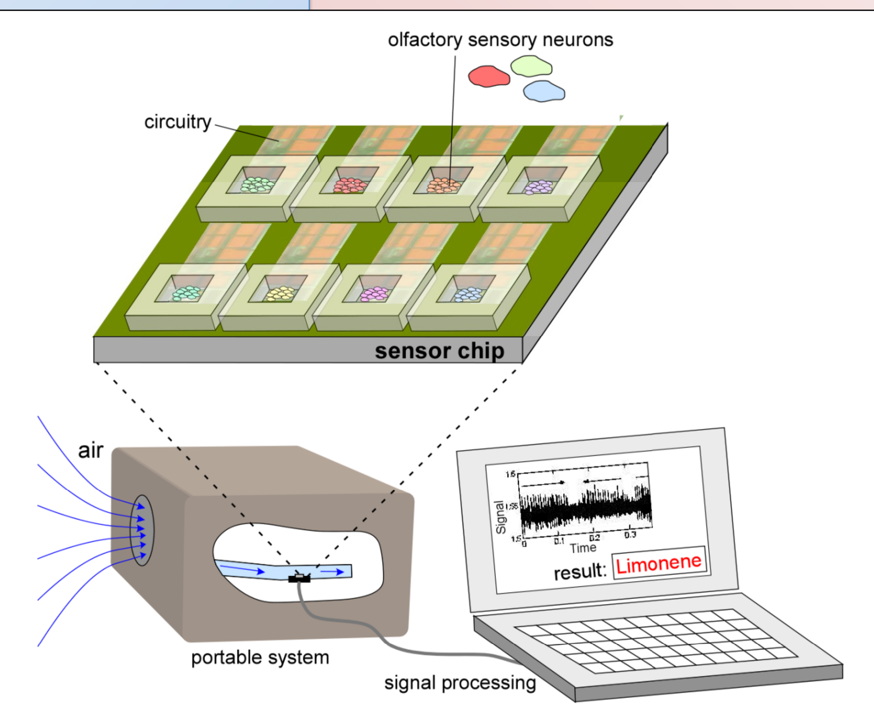

NOAA

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.



System test results
System tests show specificity to odors. Channel 14 responds odor mix 3, while Channel 15 responds odor mix 2. Both channels respond to positive control.

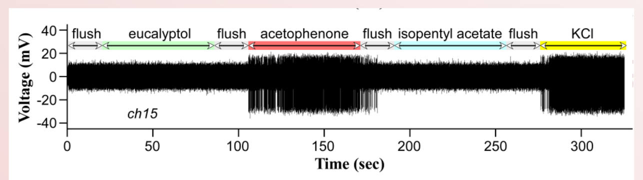




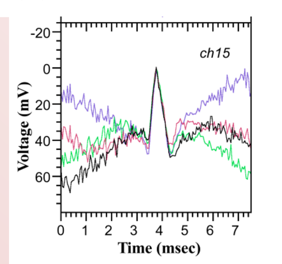
Nose on a Chip

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

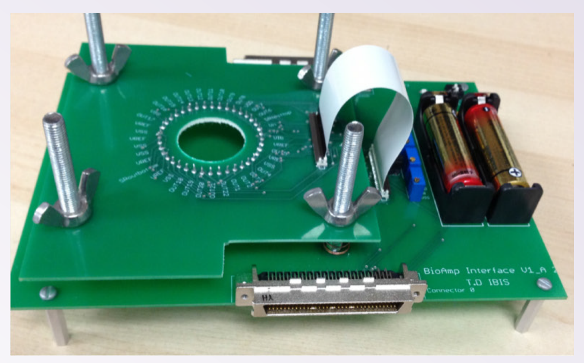
Channel 15 shows specificity to one of composing odorants of mix 2.



Spiking firing rates are consistent with reported firing frequencies.

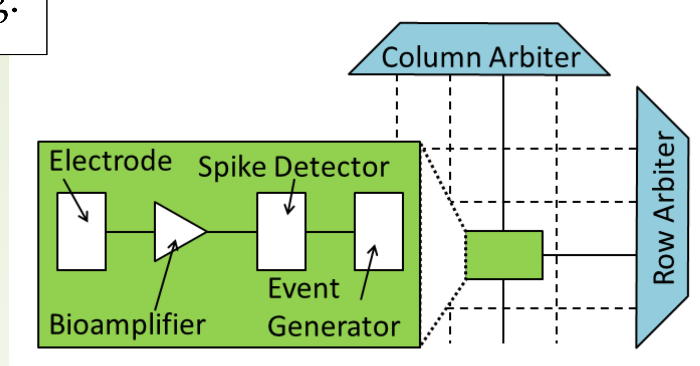


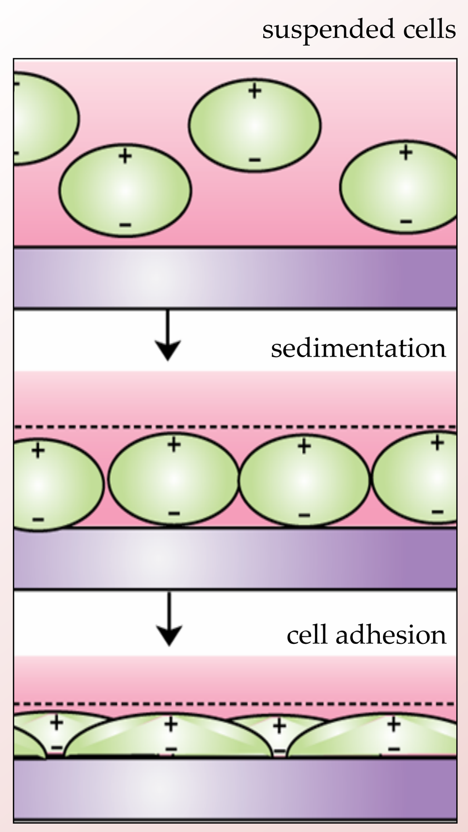
Data acquisition interface
Printed circuit board designed to connect chip pins to data acquisition system.



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

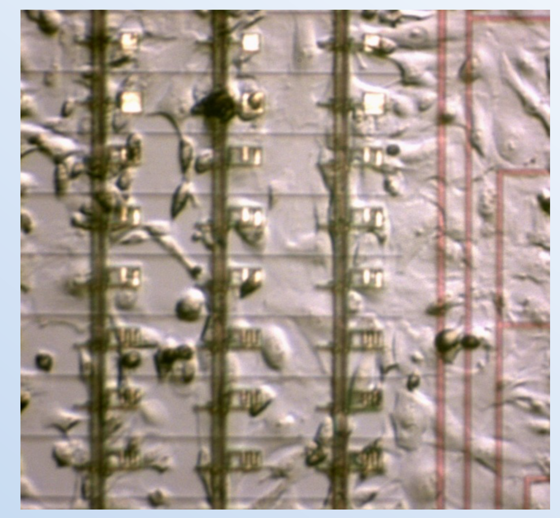
Signal processing
Active micro-electrode array comprises grid of pixels, each with bioamplifier, spike detector, and asynchronous readout.



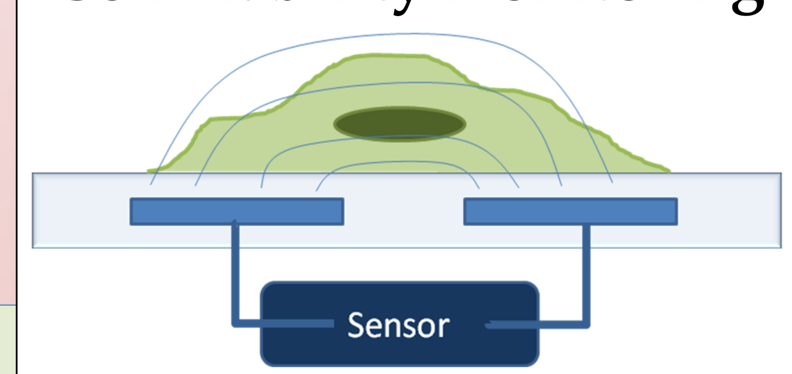


Cell adhesion
Most cultured cells are anchorage-dependent and require a solid substrate for growth. Suspended cells first sediment at the sensor surface before adhesion and proliferation.

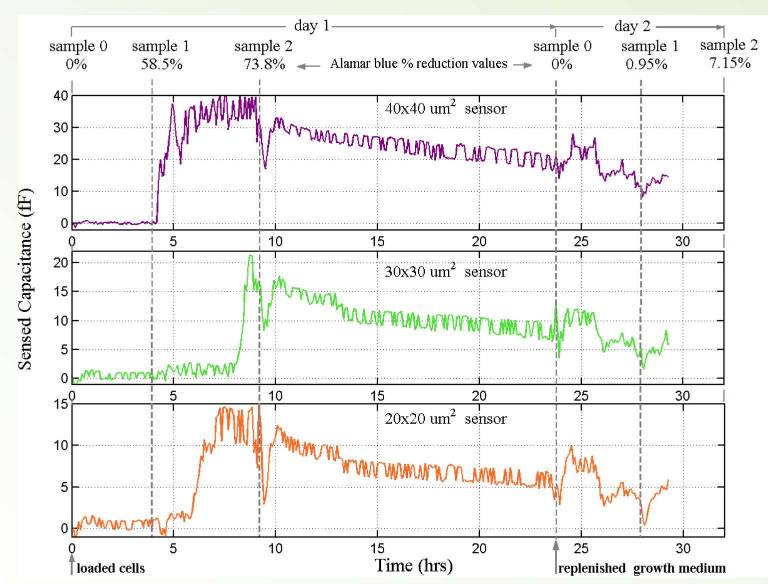
Capacitance sensing of cell viability
Cells cultured on sensing electrodes act as a variable dielectric layer. This allows the sensor to be used as an indicator of cell health and the presence of toxins.
- Unhealthy cells adhere weakly: low capacitance
- Healthy cells adhere strongly: high capacitance



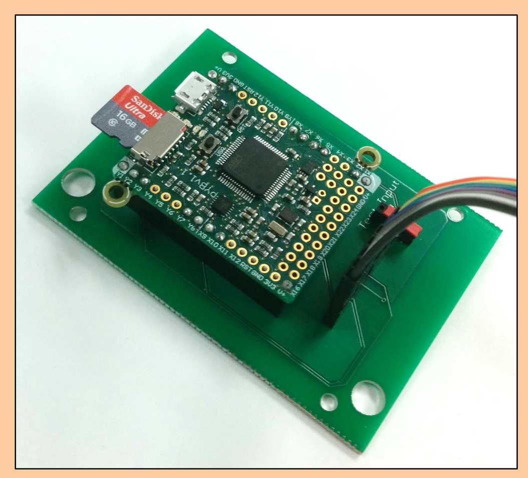
Cell viability monitoring



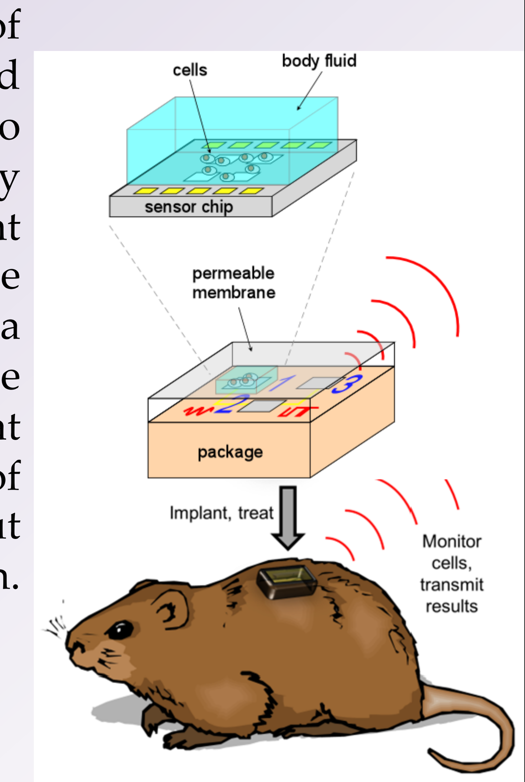
Validation of cell viability and adhesion measurements
Capacitance traces show initial sedimentation/adhesion. Traces are correlated with an independent metabolic assay.



Flexible readout interface
On-board I²C serial communications link allows readout using any COTS microcontroller. Flexible and continuous monitoring of cells.



Cancer Box
Measure the response of tumor cells and normal cells to chemotherapy drugs. Implant capacitance sensor with a permeable membrane that allows flow of molecules but keeps cells in.



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Integrated Biomorphic Information Systems Lab