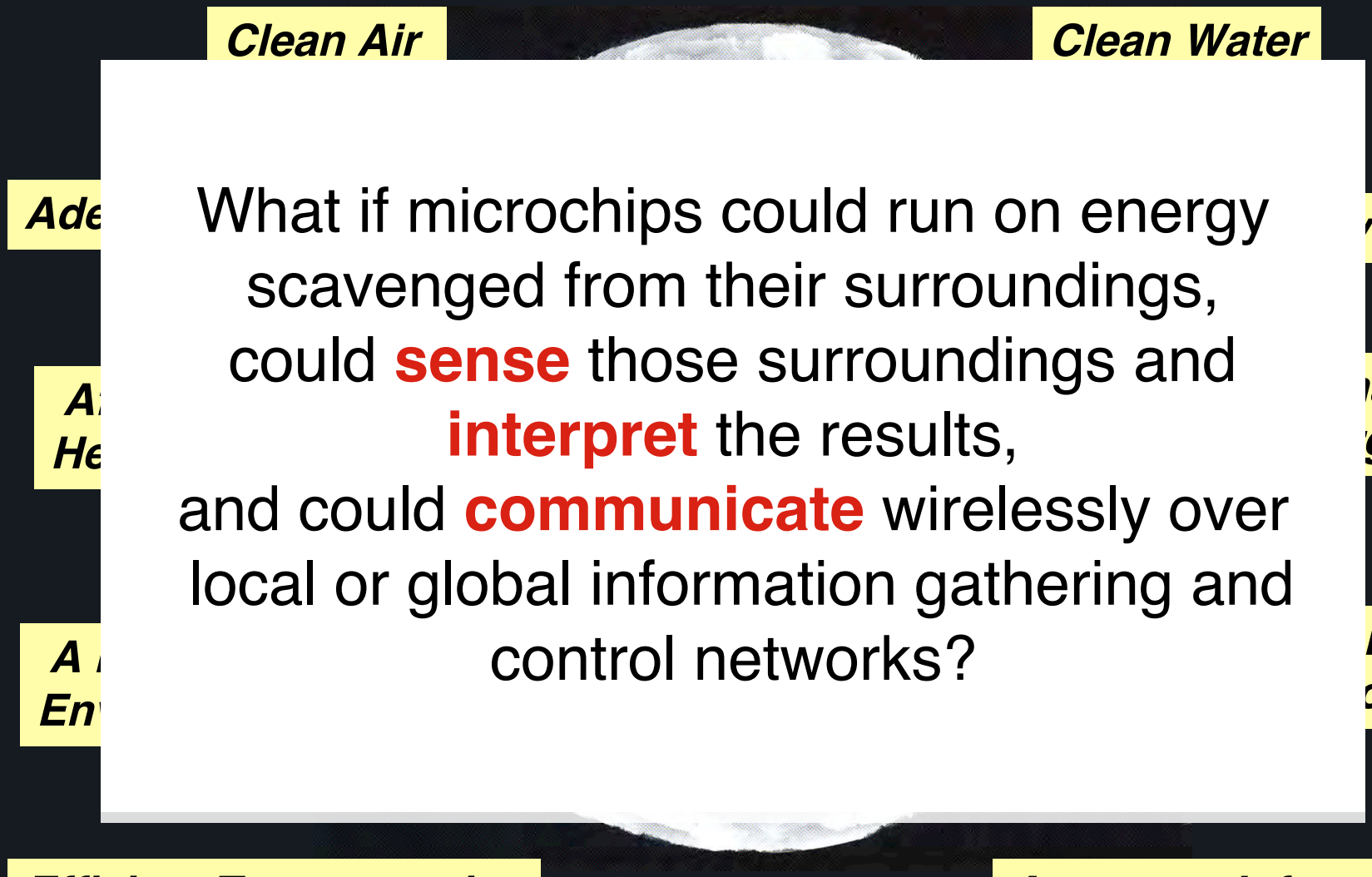
OPPORTUNITIES IN NANOMORPHIC SYSTEMS: Microsystems Based on Nanotechnology and Beyond

Kensall D. Wise

The University of Michigan

SRC/NSF Forum on Nanomorphic Systems
Stanford University
November 8-9, 2007

GLOBAL CHALLENGES FOR THE 21ST CENTURY



Clean Air

Clean Water

Ade

A
He

able
gy

A
En

le
on

What if microchips could run on energy scavenged from their surroundings, could **sense** those surroundings and **interpret** the results, and could **communicate** wirelessly over local or global information gathering and control networks?

Efficient Transportation

Access to Information

WIRELESS INTEGRATED MICROSYSTEMS

(WIMS)

MICROPOWER INTEGRATED CIRCUITS

ADVANCED POWER SOURCES

WIRELESS INTERFACES

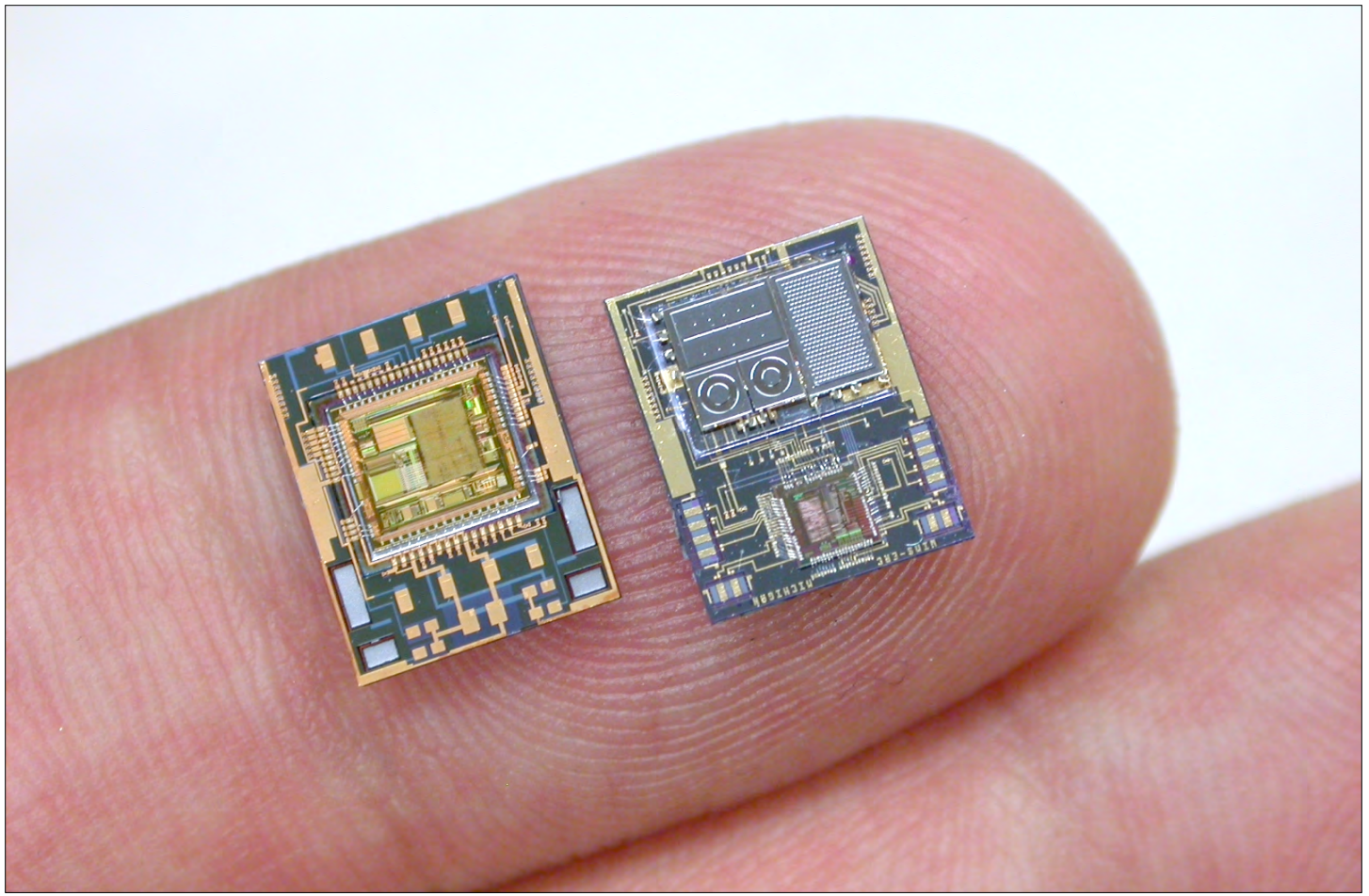
PACKAGING

MEMS

combined in a generic platform suitable

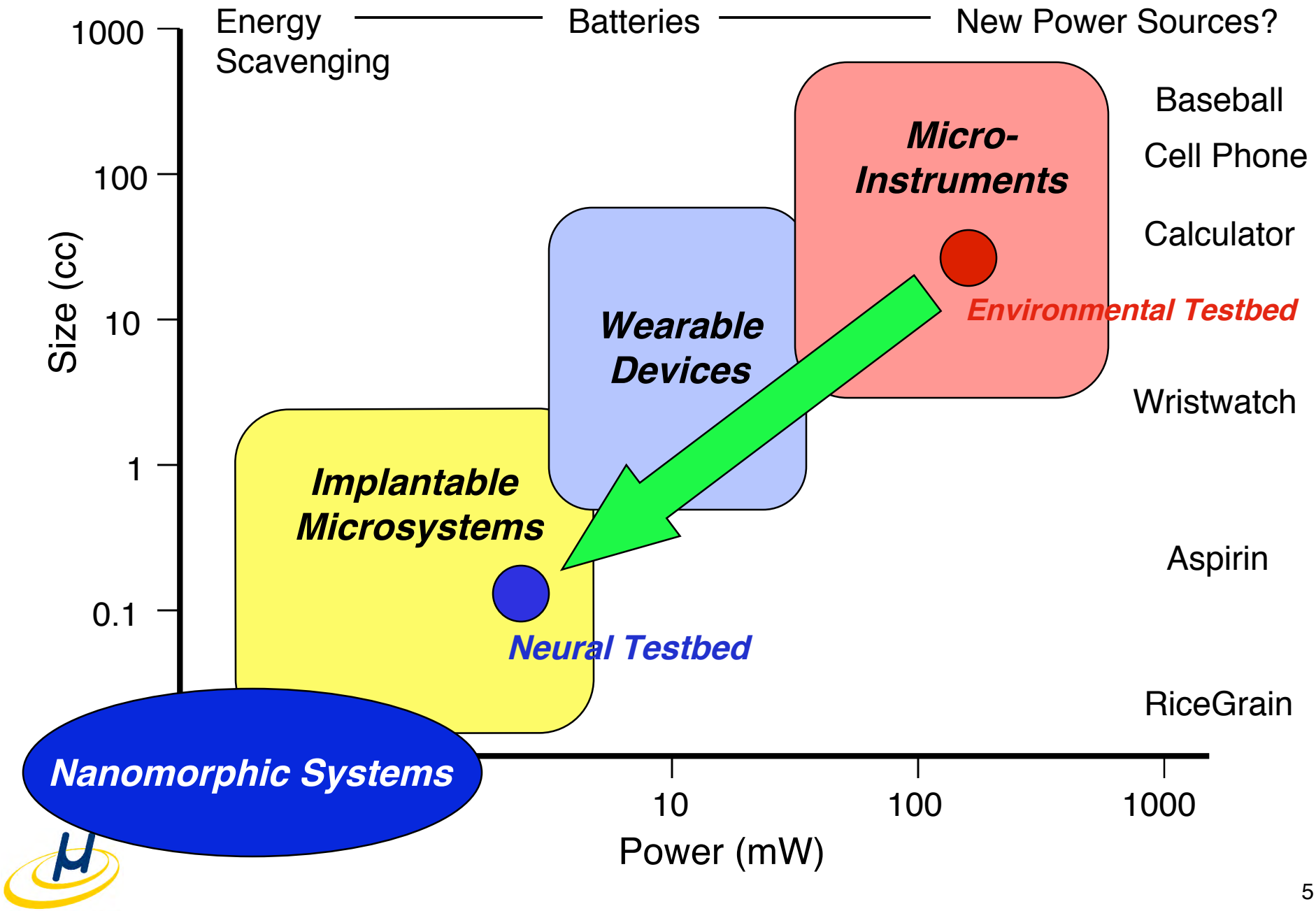
for a wide range of applications.

FULLY-INTEGRATED MICROSYSTEMS FOR AUTONOMOUS DATA GATHERING

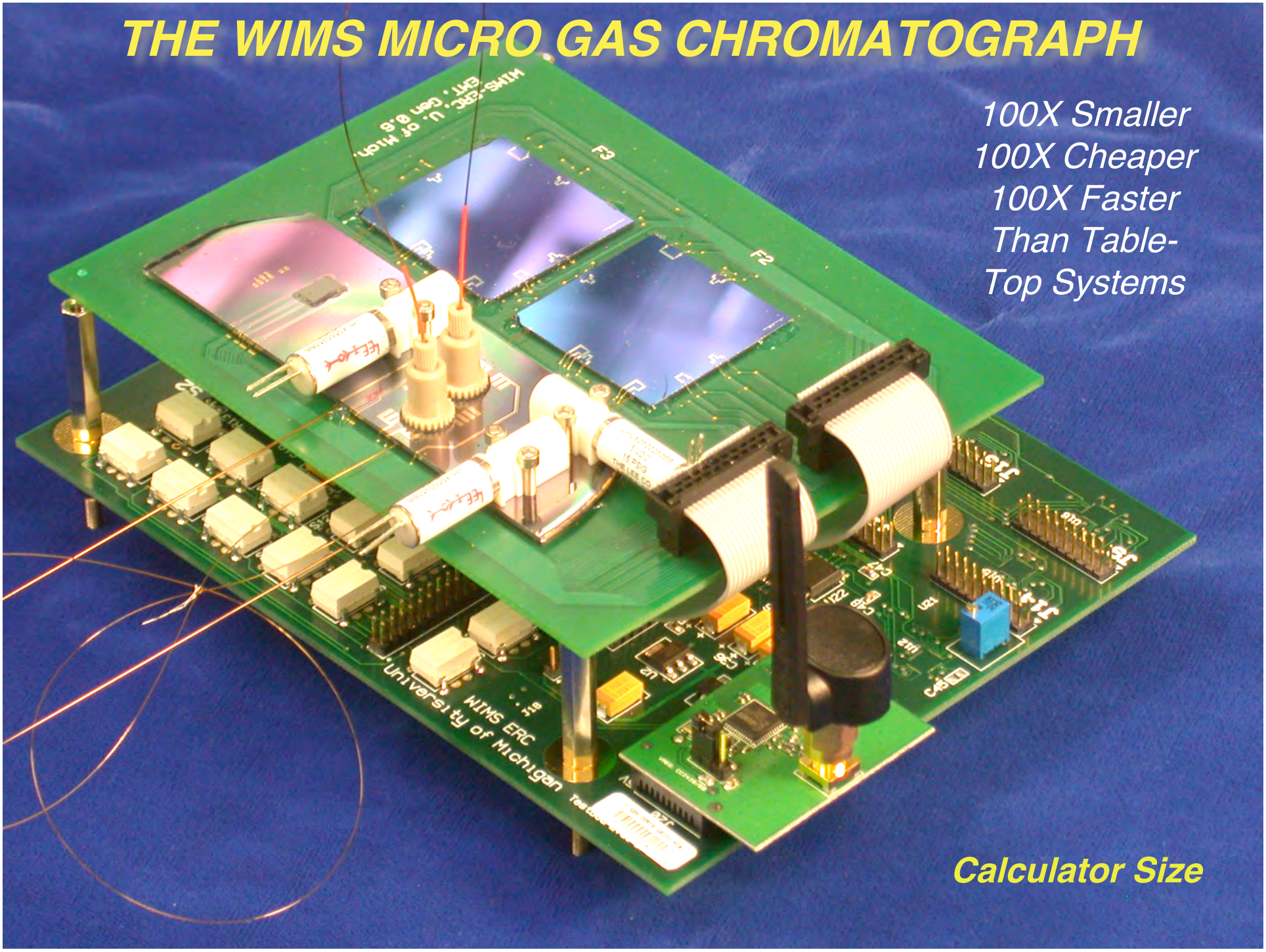


Embedded μComputer, 16Mb Flash Memory, Sensors for Pressure, Temperature, Humidity, and Off-Chip Biosignals

MICROSYSTEM DRIVERS: Power and Size



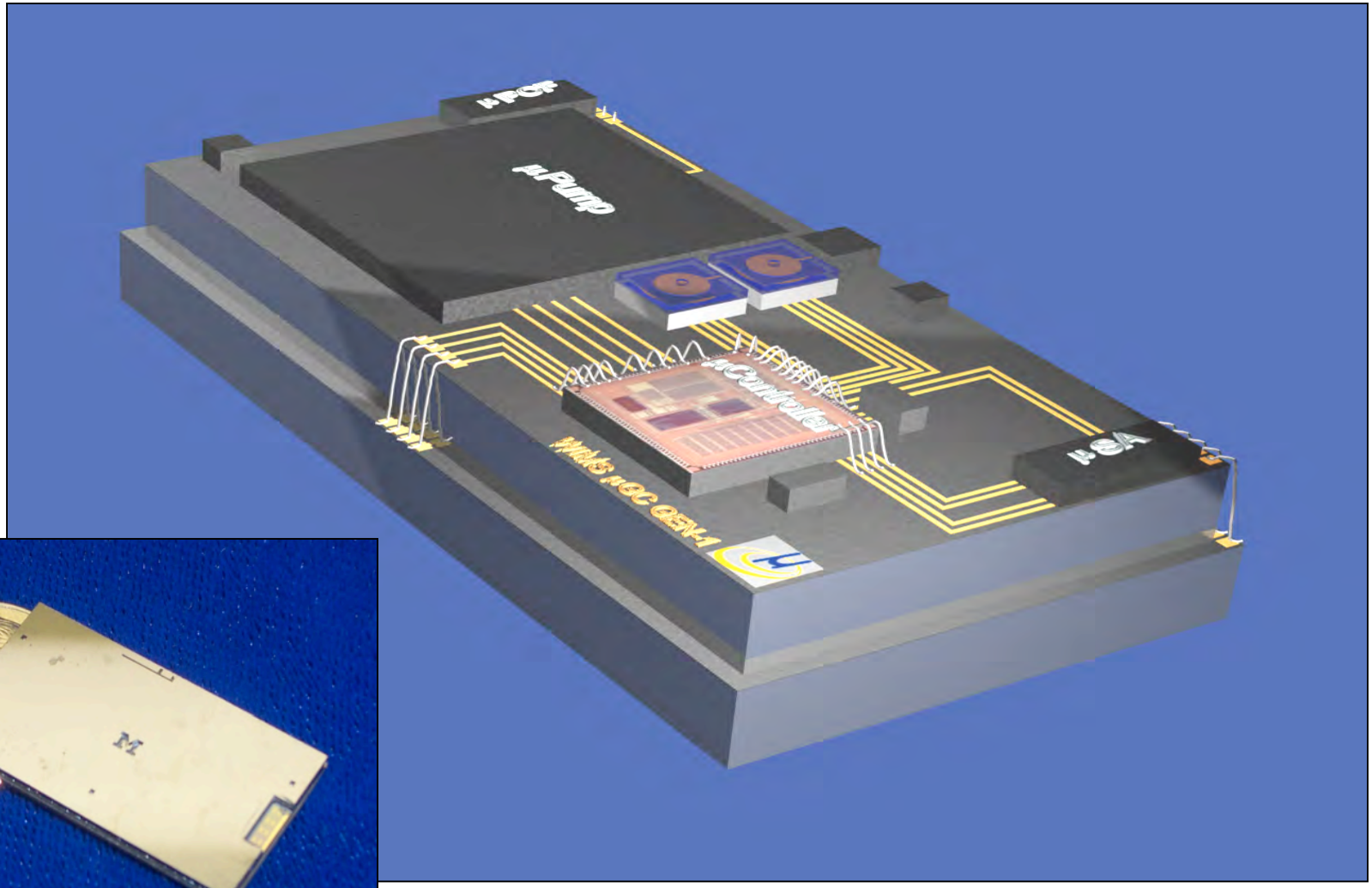
THE WIMS MICRO GAS CHROMATOGRAPH



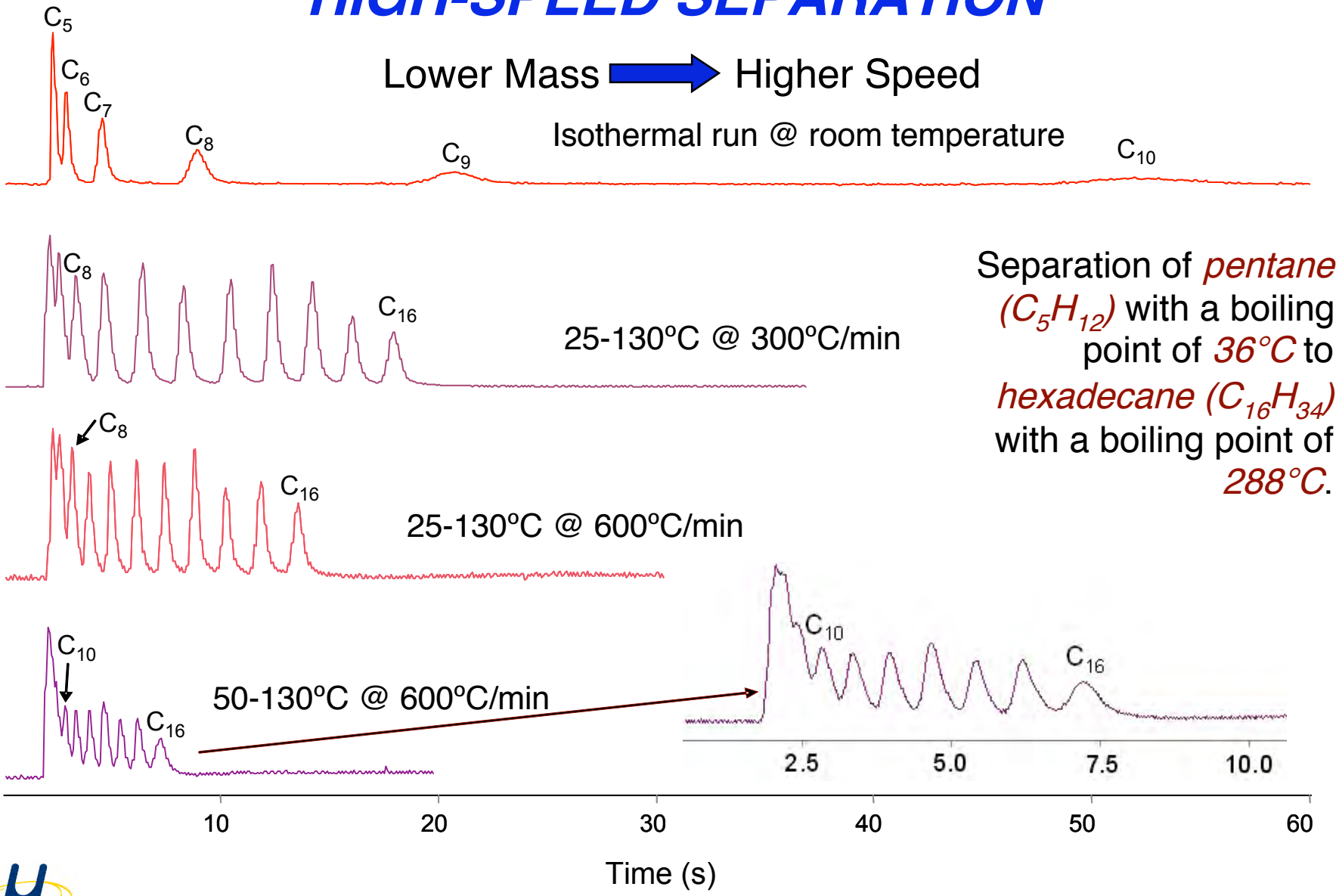
100X Smaller
100X Cheaper
100X Faster
Than Table-
Top Systems

Calculator Size

TOWARD A WRISTWATCH-SIZE μGC



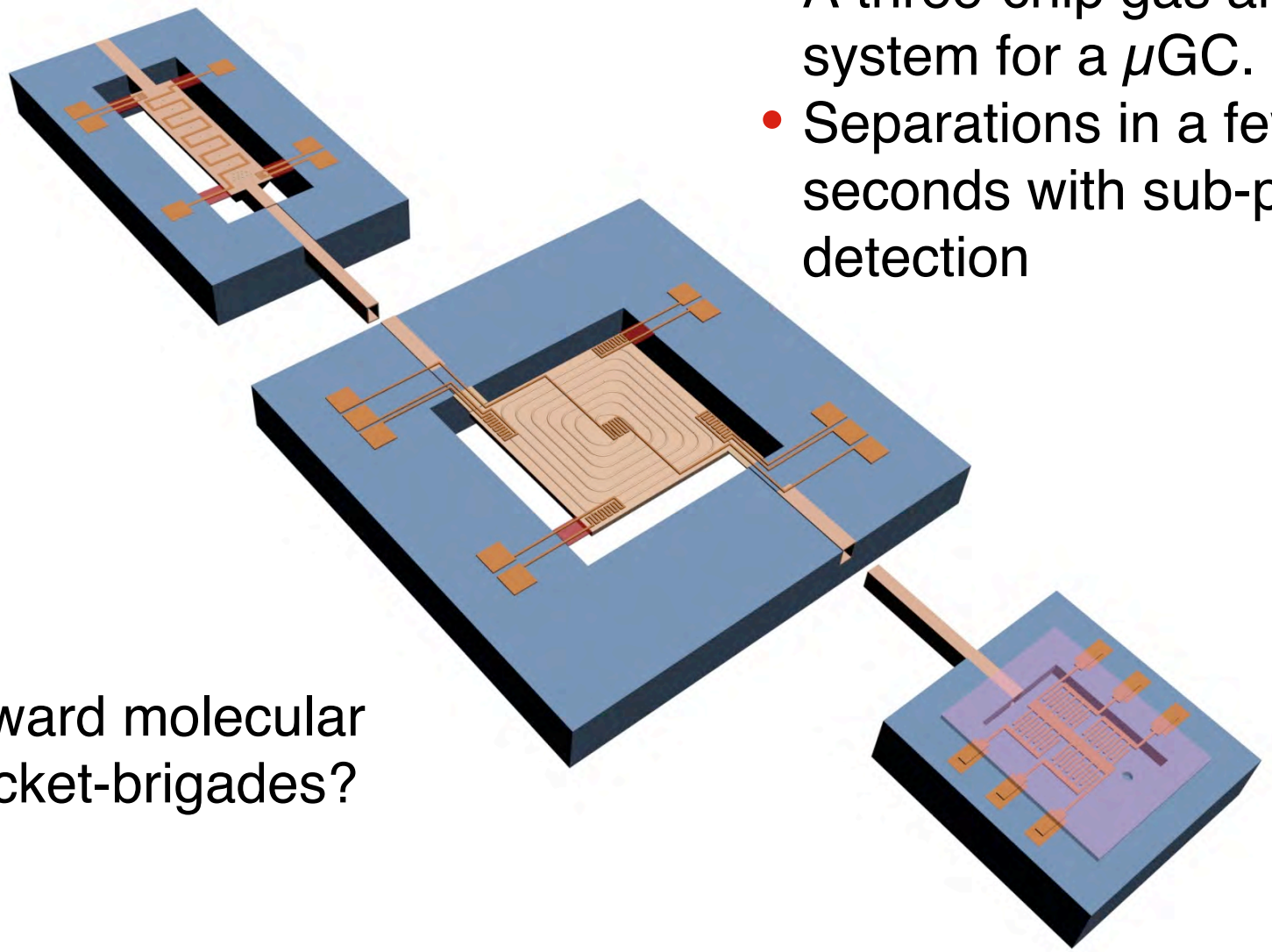
TEMPERATURE PROGRAMMING FOR HIGH-SPEED SEPARATION



Separation of *pentane* (C_5H_{12}) with a boiling point of *36°C* to *hexadecane* ($C_{16}H_{34}$) with a boiling point of *288°C*.

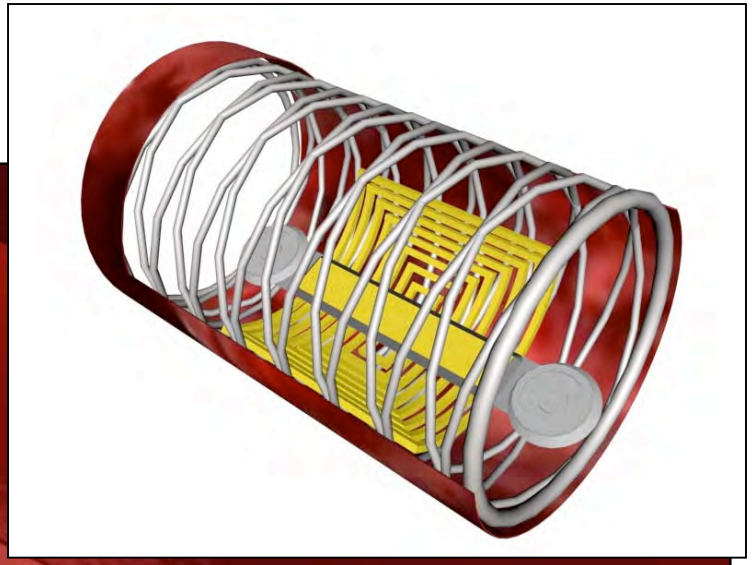
DEVICE SCALING: BEYOND WRISTWATCH-SIZE?

- A three-chip gas analysis system for a *μ*GC.
- Separations in a few seconds with sub-ppb detection



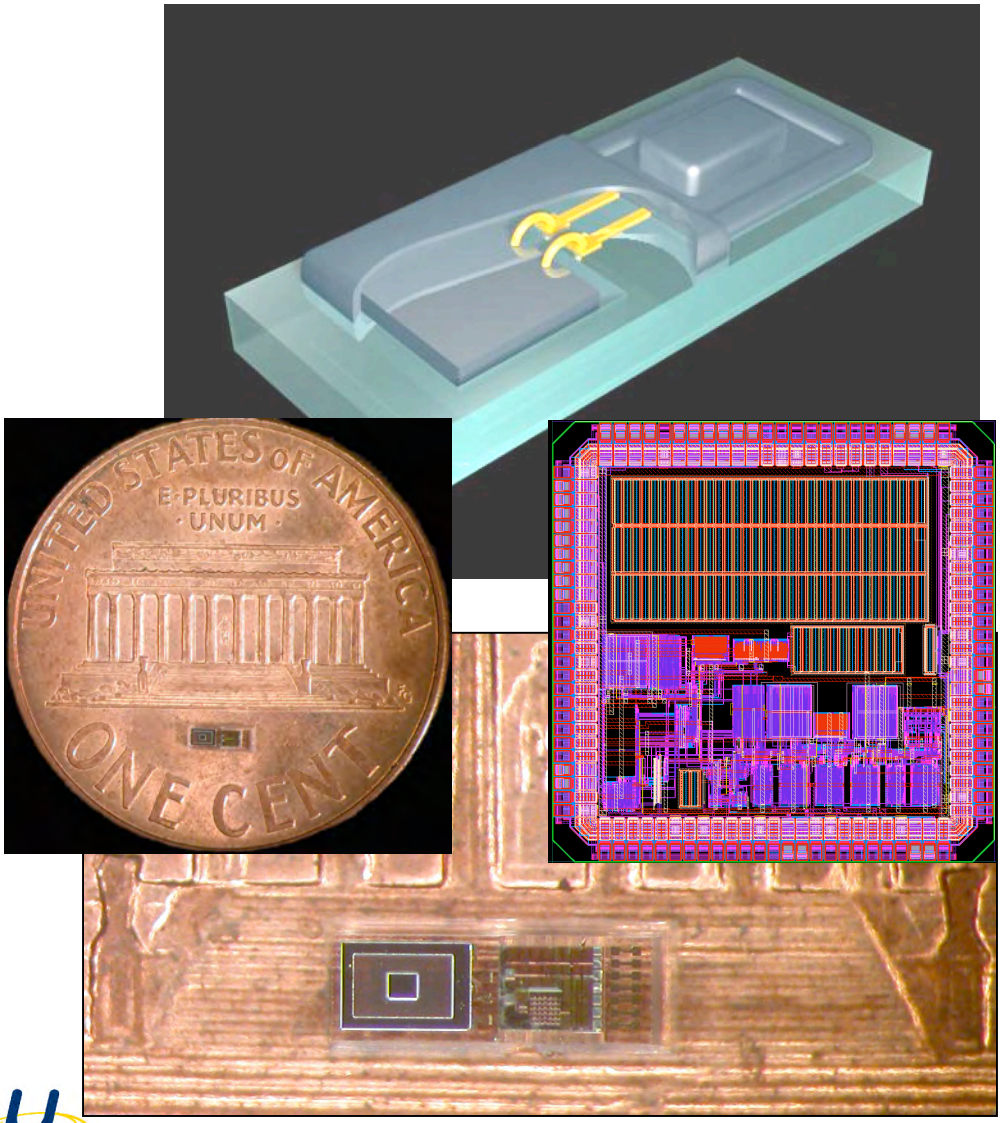
Toward molecular bucket-brigades?

ACTIVE STENTS: Intra-Arterial Sensing of Pressure/Flow



Suitable for the carotid arteries; not yet small enough for the coronaries.

WIRELESS SENSING OF INTRAOCULAR PRESSURE FOR THE TREATMENT OF GLAUCOMA

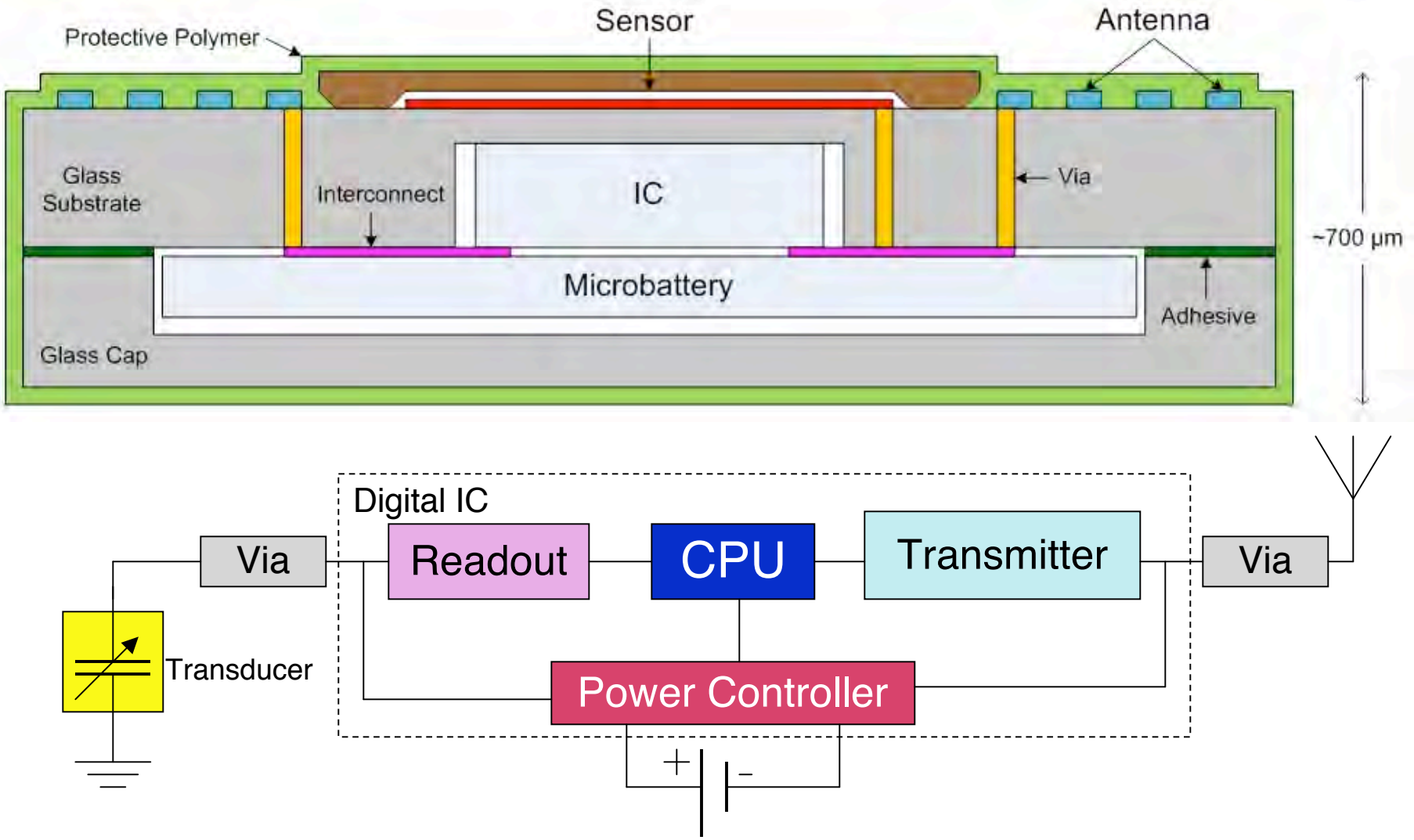


- Measures intraocular pressure every 15 minutes
- RF read out, once per day
- Capacitive silicon pressure sensor operating into the “Subliminal” processor
- Range: 0-50mmHg relative; 550-850mmHg absolute
- Power: <10nW, supplied by energy scavenging.
- Accuracy: ±1mmHg
- Size: 0.5mm x 0.7mm x 1.5mm

- ***Major challenges in energy scavenging, packaging, and readout***

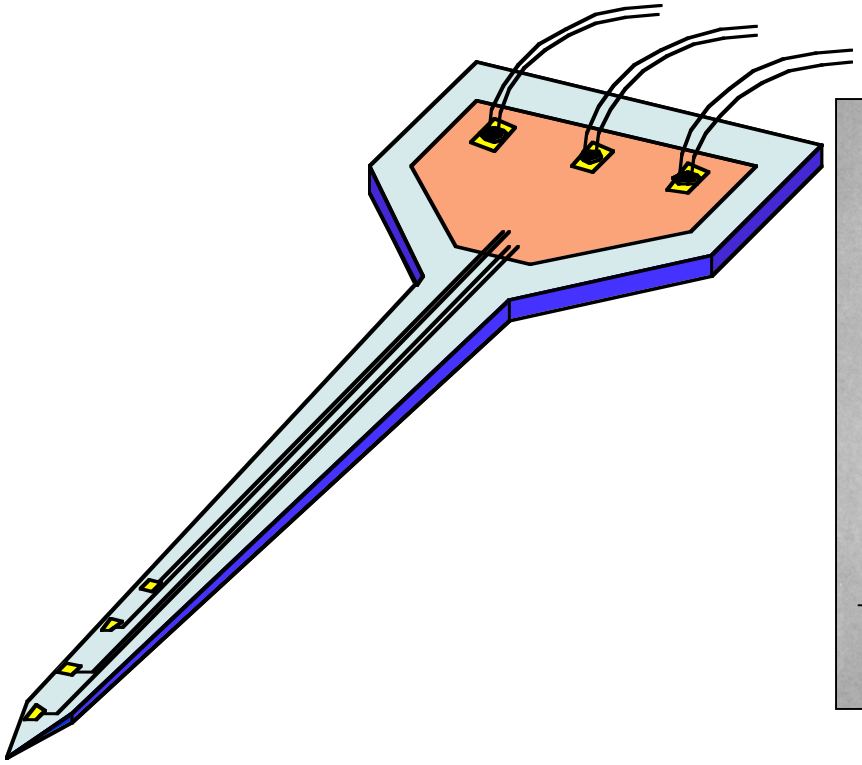
AN INTEGRATED INTRAOCULAR GLAUCOMETER

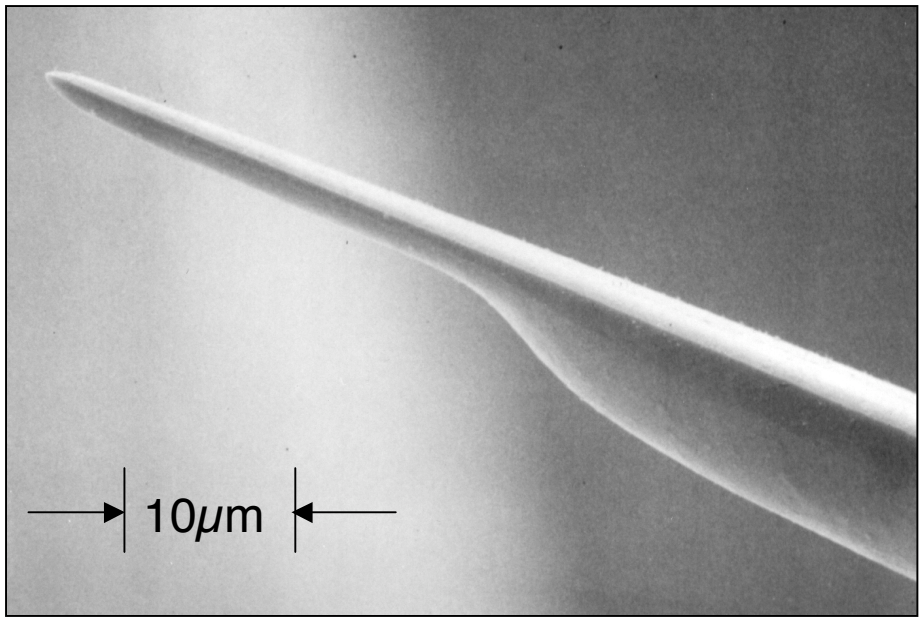
Module Overview



A CHRONIC CELLULAR INTERFACE

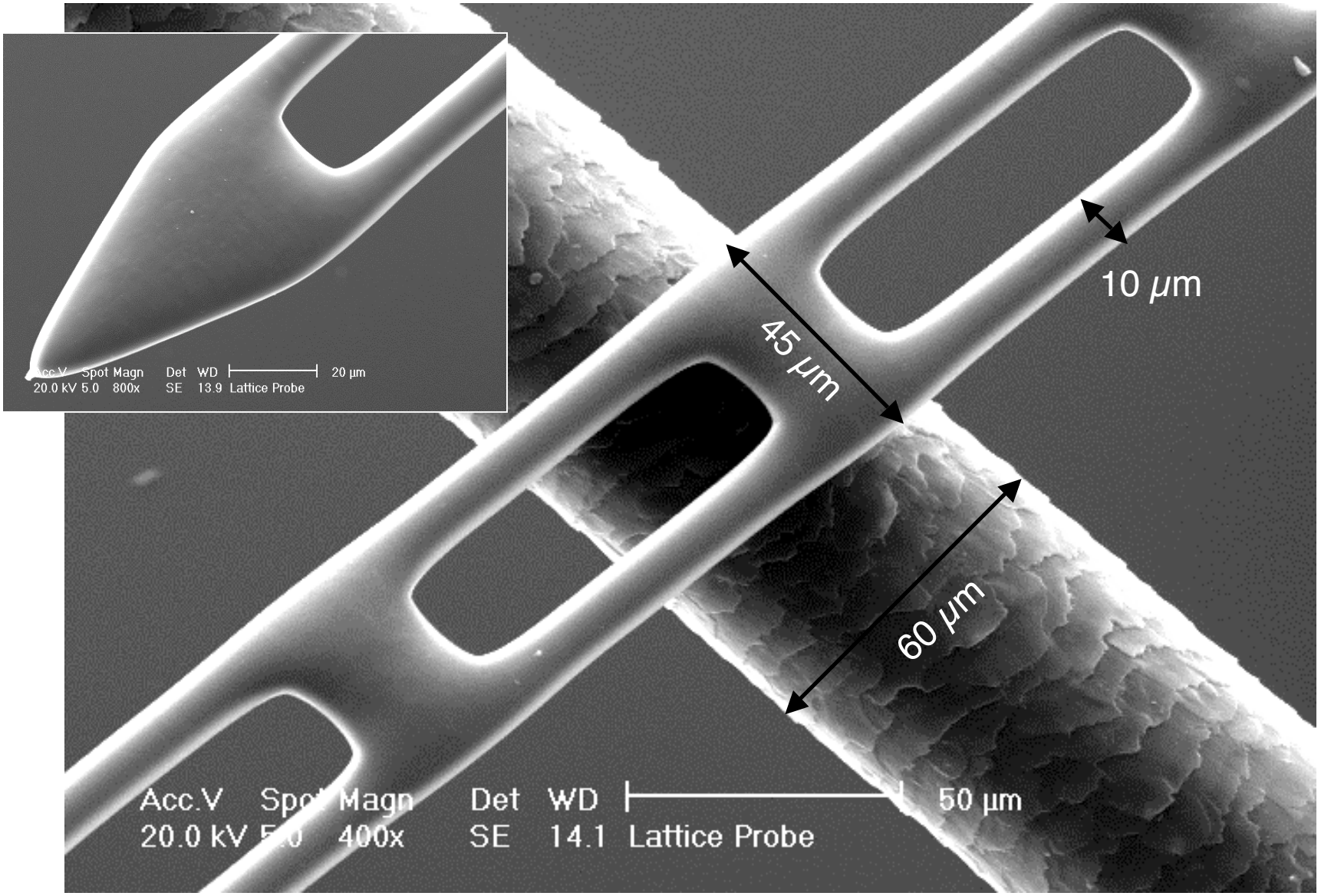
Indwelling in Tissue: An Electronic Interface with the Brain

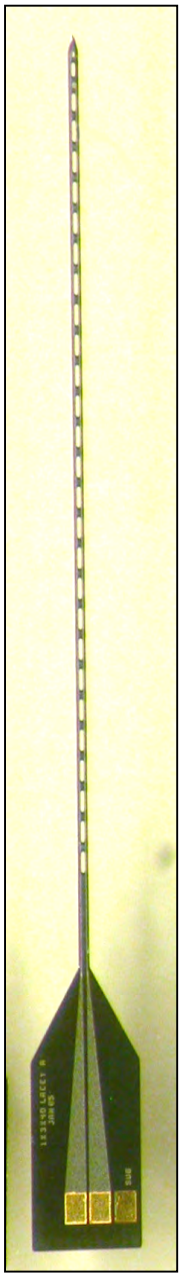




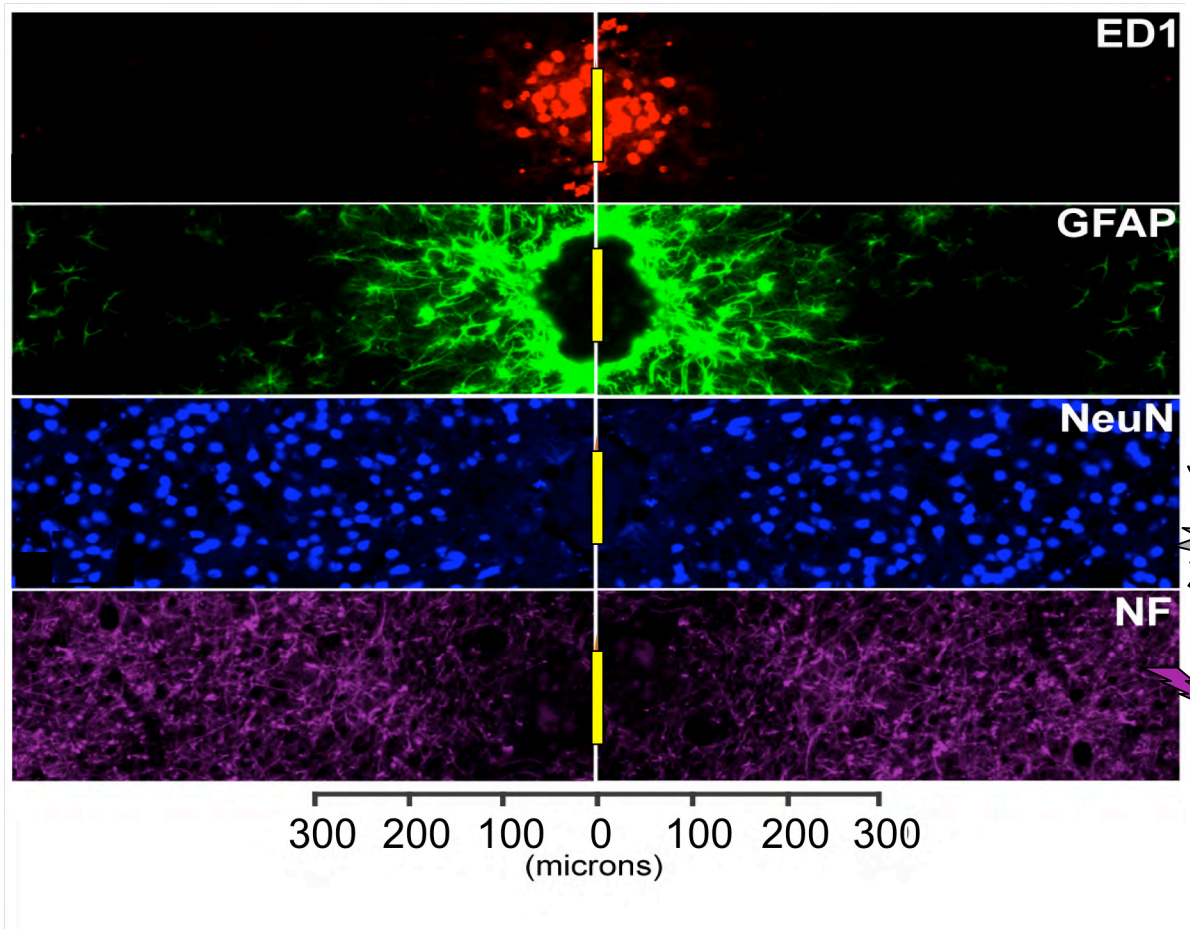
- Lithography allows all dimensions to be defined within ±1μm
- ***Limited by strength, not technology***
- Substrates defined using boron etch-stops or SOI
- Widely used in neuroscience

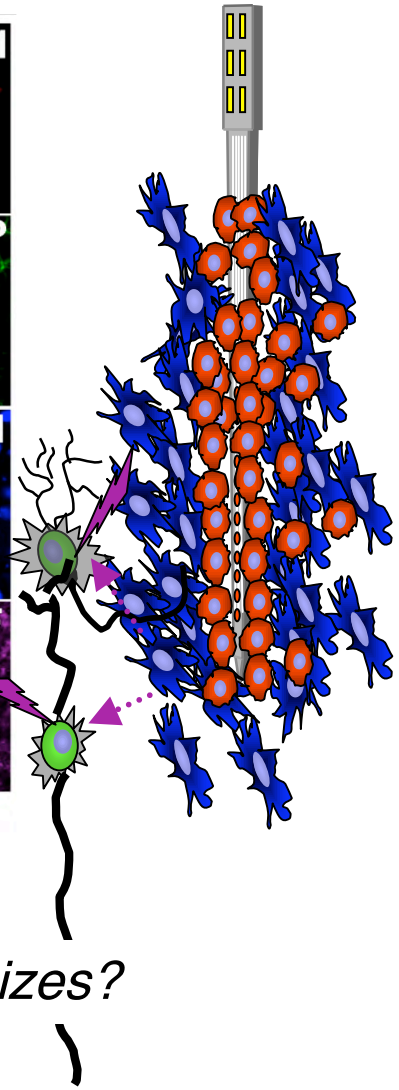
SHRINKING PROBES TO CELLULAR DIMENSIONS





TISSUE REACTION STUDIES





Does the tissue ignore the device at very small sizes?

A Collaboration with Patrick A. Tresco, University of Utah

CONCLUSIONS

- The ability to sense, interpret, and communicate using WIMS will have a revolutionary impact on the gathering of information during the coming decade. Most of these microsystems will have dimensions of a millimeter or more.
- Nanomorphic systems having micron dimensions will have to overcome significant challenges in ultra-low power circuits, energy scavenging, packaging/microassembly, wireless communications, and (especially) sensors.
- Scaling to micron and submicron sizes will be key in realizing improved sensors, e.g. using CNTs.
- Applications for nanomorphic systems will likely be found at the cellular level, forming bridges between microelectronics and biological systems and yielding real breakthroughs during the next several decades.