

Flexible Sensors, Substrates for Medical Applications

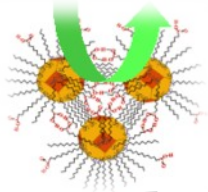
Jim Turner



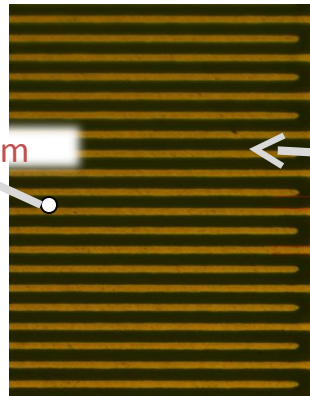
Flexible Sensor Arrays on Polymer Substrates

features in Cu on PET built at the CAMM

VOC's

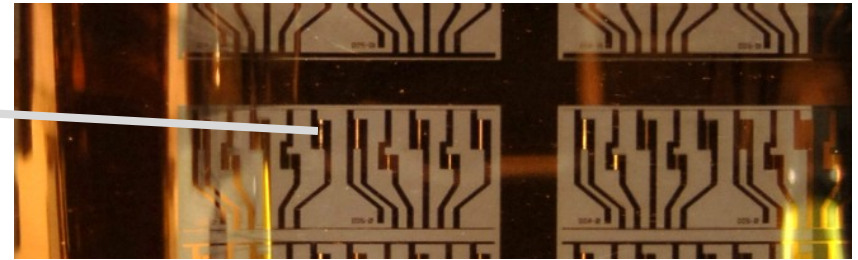


10nm



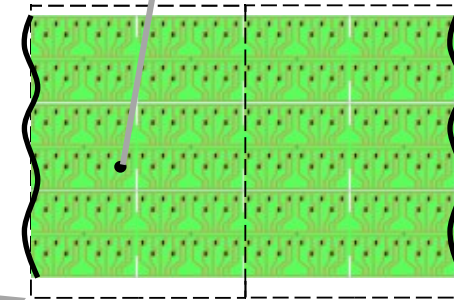
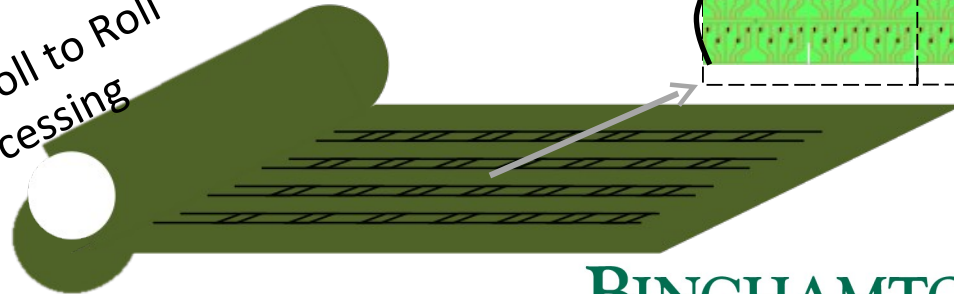
4 μm line/space

Roll to Roll Sensor array built at the CAMM



Millimeters

Roll to Roll Processing



Centimeters

C J Zhong & B Sammakia
Binghamton University

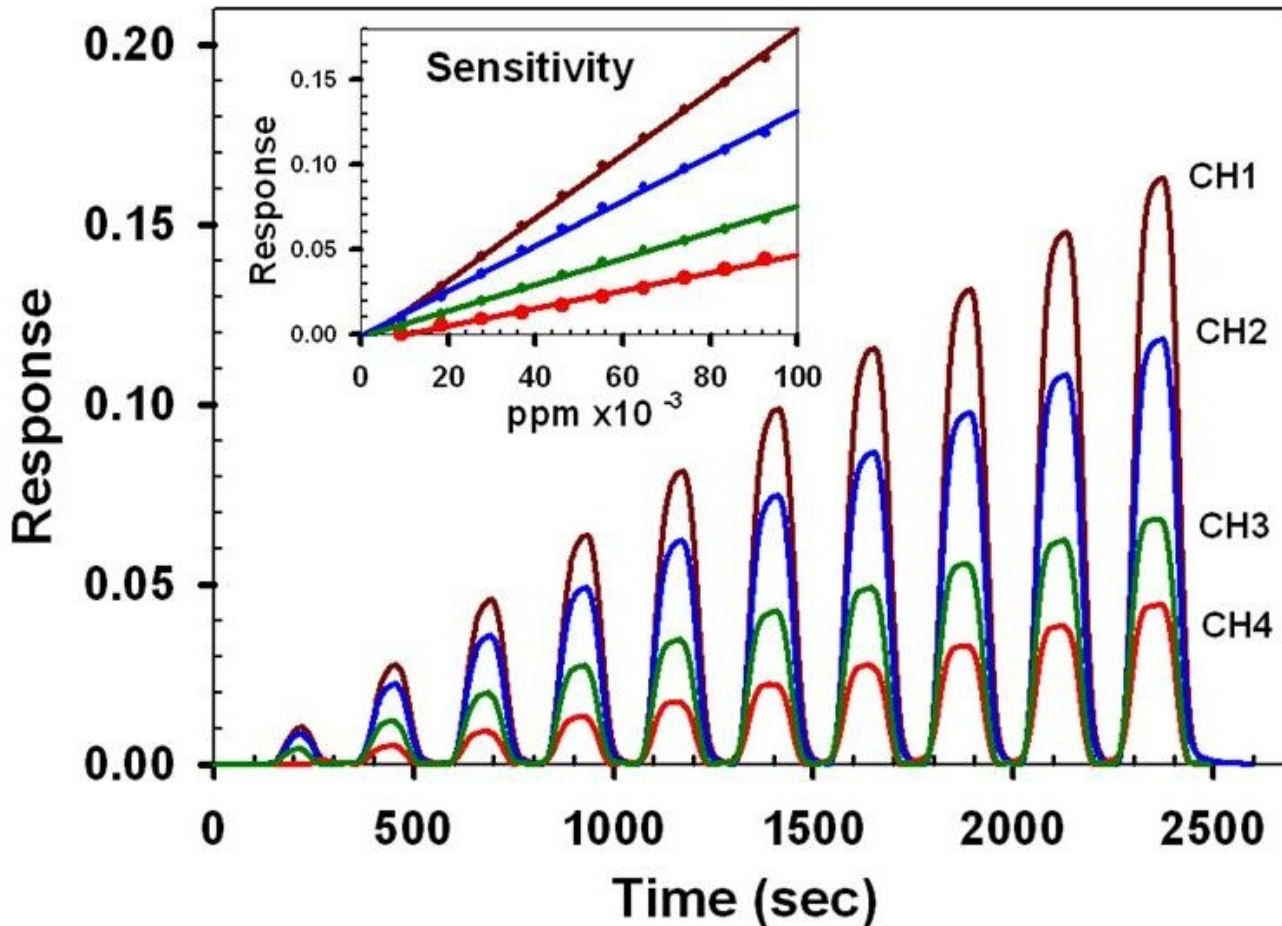
Up to 300 Meters

BINGHAMTON
UNIVERSITY
STATE UNIVERSITY OF NEW YORK

SIP
The Small Scale Systems Integration
and Packaging Center

Breath Acetone Detector

Zhong Research Group



Response and Sensitivity profiles for a nanostructured sensor array to acetone vapor

Ideal Electronics for Biology & Medicine

- ✓ Geometric conformability
 - direct biological interaction
- ✓ Biocompatibility
 - mechanical
 - surface chemistry
- ✓ Scalability
 - micro to human size
- ✓ On-board electronics
 - rapid detection & analysis
 - communication
 - alarms
 - on-board & remote decision making
- ✓ Low cost
 - ubiquitous application
 - disposable



Types of Biomedical Devices

External:

Remote sensing or skin contact

Biological sample:

Clinical chemistry

Body fluids

Cell or Tissue

Direct Tissue Contact:

Sensors

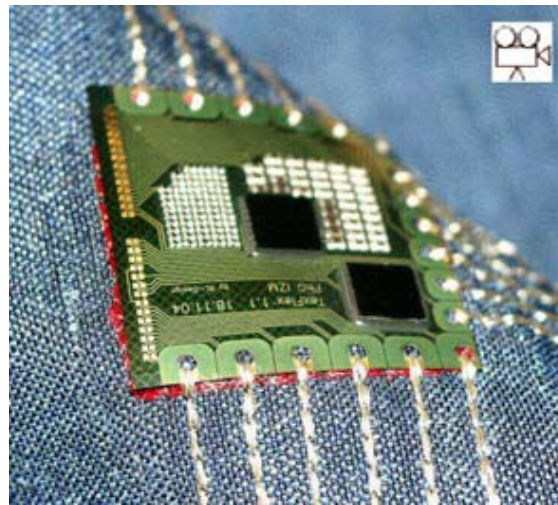
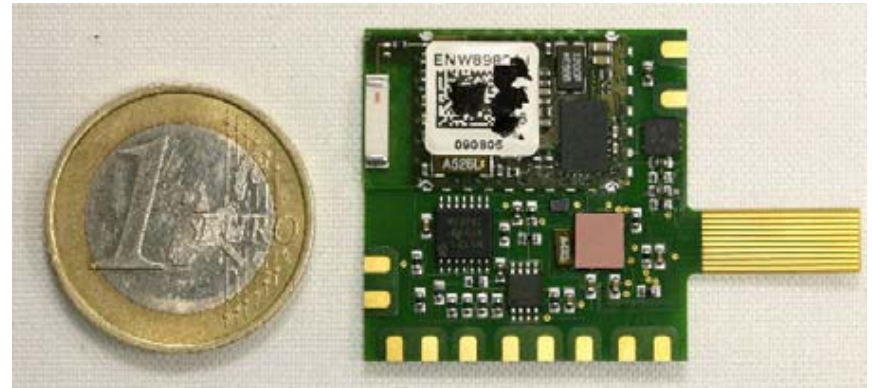
Bandages

Implants

Wearable Monitors:

- ✓ Health history
- ✓ General health monitor vital functions
- ✓ At risk population infants, elderly, physically impaired
- ✓ Specific Disease cardiac, diabetes
- ✓ Telemetric communication
GPS - rapid response

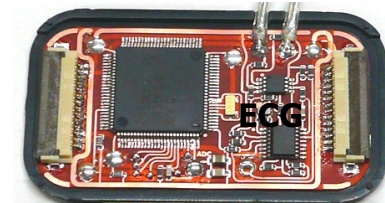
EKG Shirt



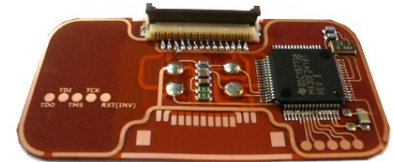
T Linz et al. Proc Int Workshop Wearable & Implantable Body Sensor Networks (BSN06) IEEE



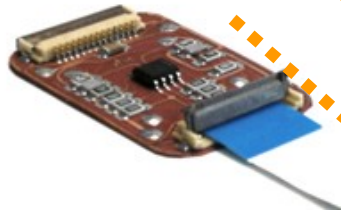
electrode, dry or sticky



MCU (micro-controller unit)



rechargeable battery supply



temperature sensor



memory card storage

Bluetooth wireless transceiver





Additional Sensors for 2010

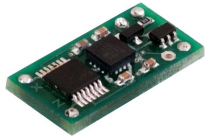
speaker and microphone



microphone



3 axis accelerometer



gas monitors



pulse-ox



With the additional sensors, the following physiological signals can be monitored:

Respiratory rate
Body temperature
Heart rate

Blood oxygenation
Inspired gas content
Expired gas content

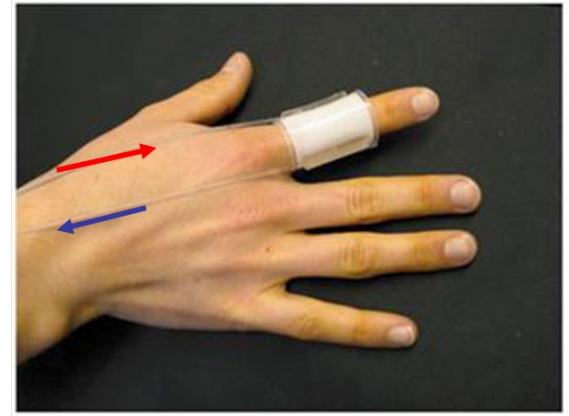
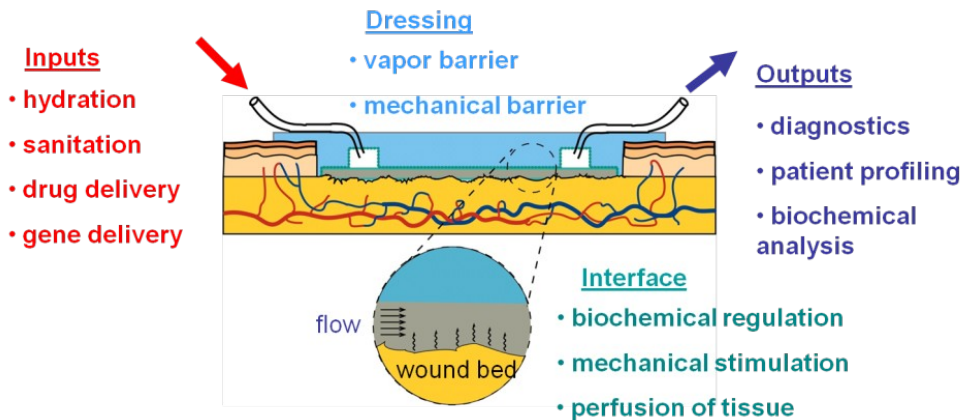
ECG
Motion & Position
Speech/Coughing



The Small Scale Systems Integration and Packaging Center

Smart Bandages for Wound Healing

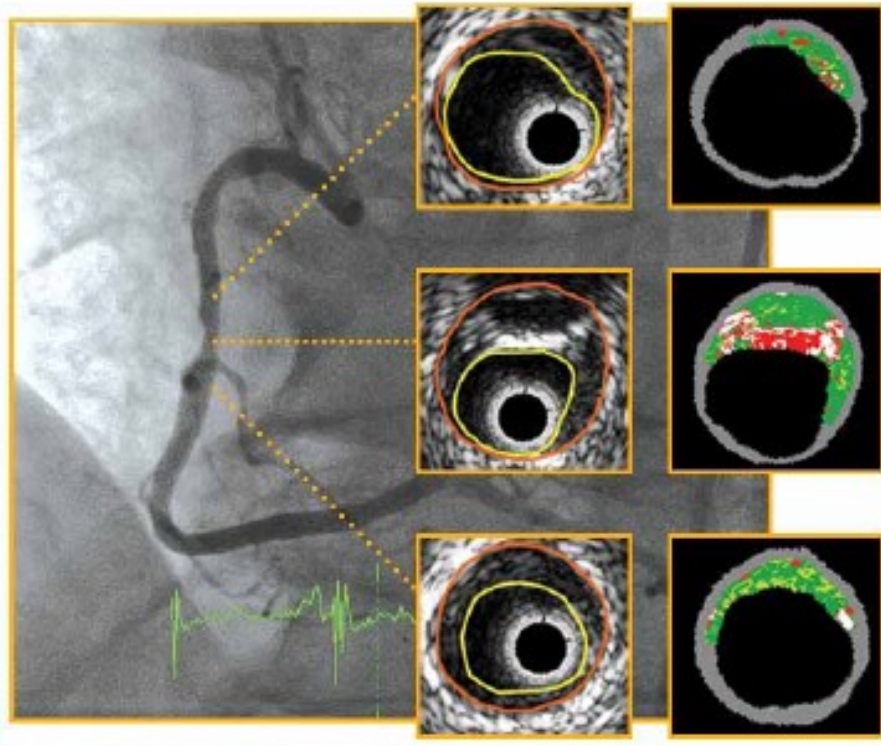
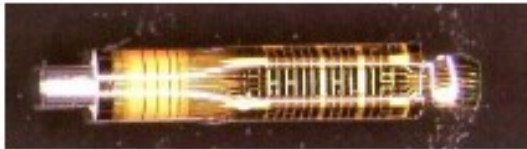
- ✓ Unhealed wounds \$750 million/yr in USA
 - labor intensive
- ✓ Diabetic ulcers & Pressure wounds (Bedsores)
 - large numbers of individuals



Cabodi, M., Choi, N. W., Gleghorn, J. P., Lee, C. S. D., Bonassar, L. J. & Stroock, A. D., A. Microfluidic Biomaterial. *Journal of the American Chemical Society* 127, 13788-13789 (2005).

CAMM Enables Industry Technologies– EI and Partners Medical Device Built at CAMM

Percutaneous Medical Device



- Flexible PI substrate
- PZT (receiver/transmitter)
- multiple flip chip die
- 22 μm bumps on 70 μm pitch

“These are some of the finest pitched, soldered interconnect flip chips in production anywhere in the world today.”

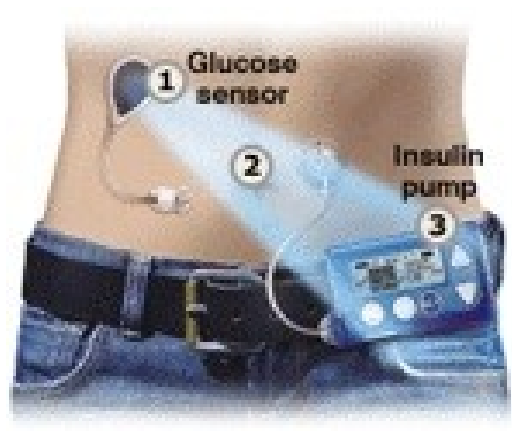
Part of an IVUS catheter device, which provides an ultrasound image from inside a coronary artery and is used to diagnose and assess vascular and structural heart disease.

Soft Tissue Implants

- ✓ Replace lost function
 - disease
 - in-born deficits
 - traumatic injury
- ✓ Acute & chronic tissue integration
 - mechanical and chemical match
- ✓ Normal tissue component distribution
 - ratio & distribution of cell types
 - connective tissue

Transdermal Glucose sensor

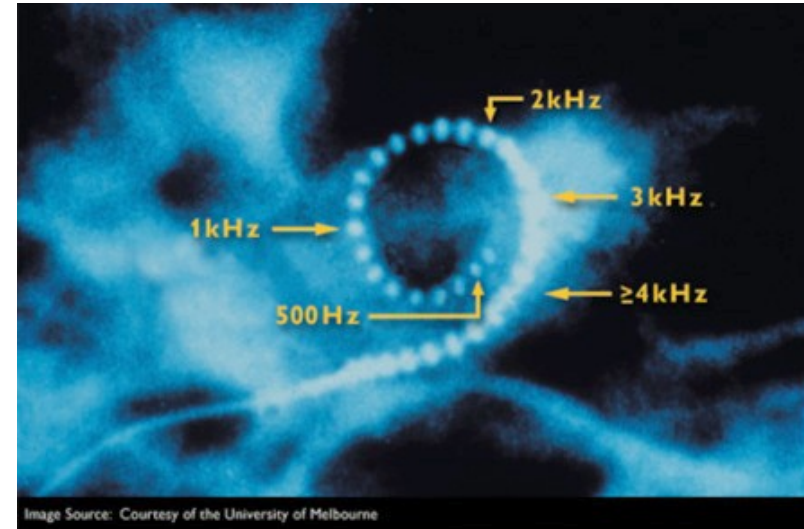
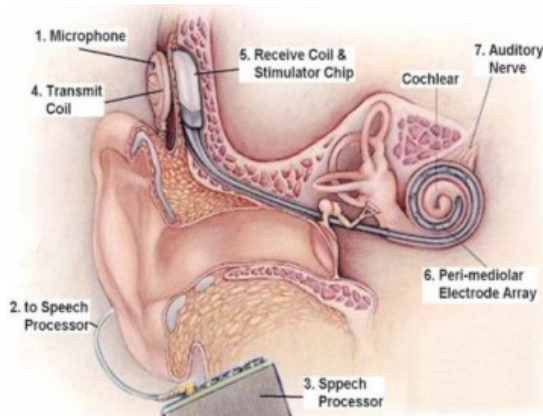
Continuous monitoring & insulin adjustment



Paradigm Veo System, medadget.com/archives/medicine
September 23, 2009

Cochlear Implants

- ✓ severely hearing impaired
- ✓ Over 100,000 implants in use world wide



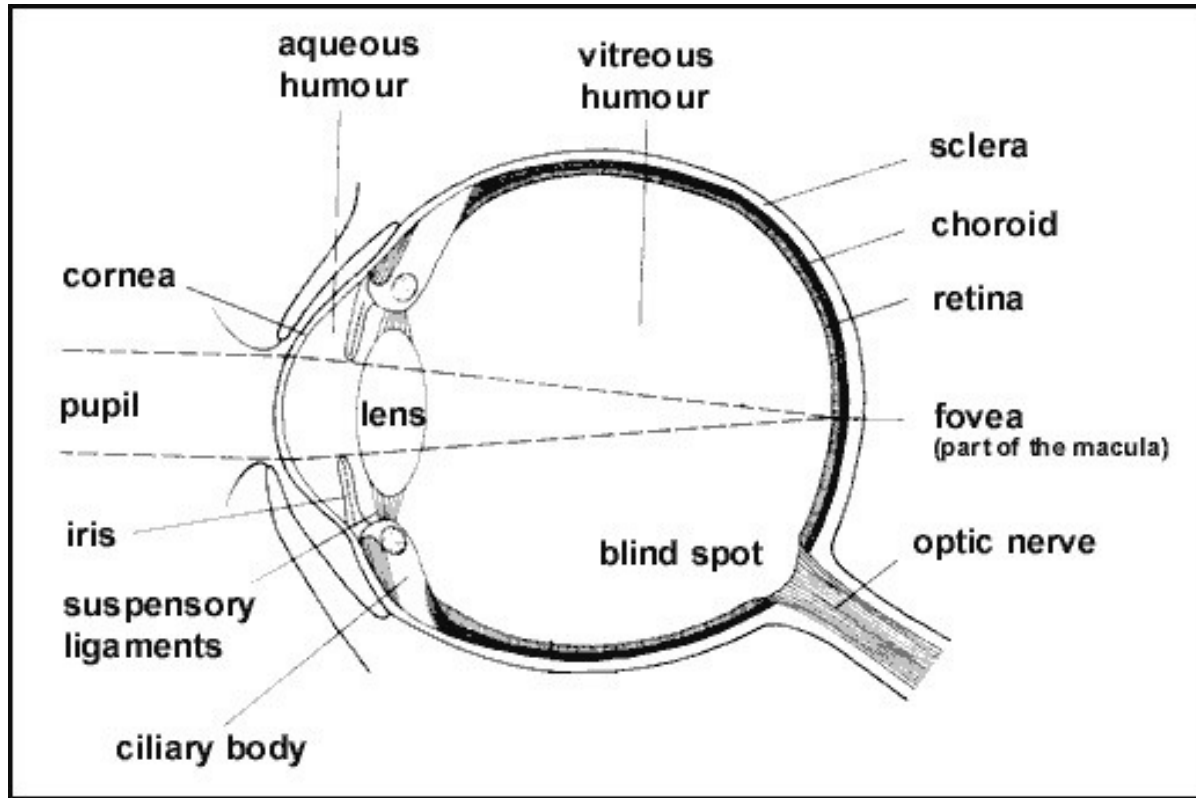
- ✓ Miniaturization
- ✓ More microelectrodes

<http://helios.snu.ac.kr>

<http://www.hearinglosseducation.com>

</Implants/129.asp>

Eye Implants



<http://www.internal.schools.net.au/edu>

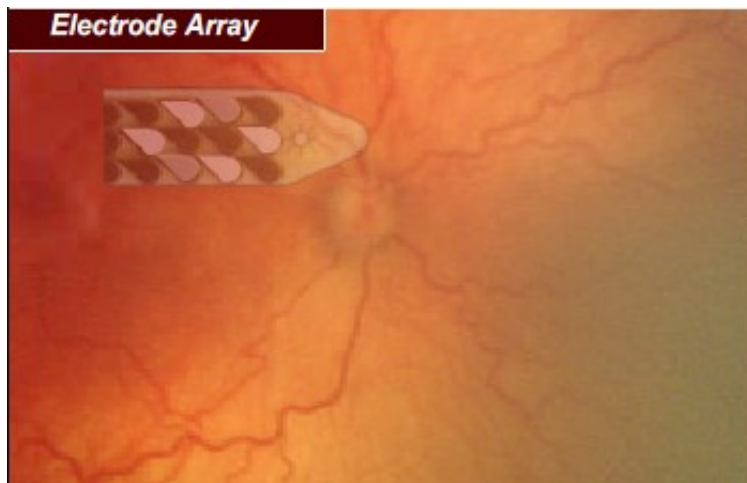
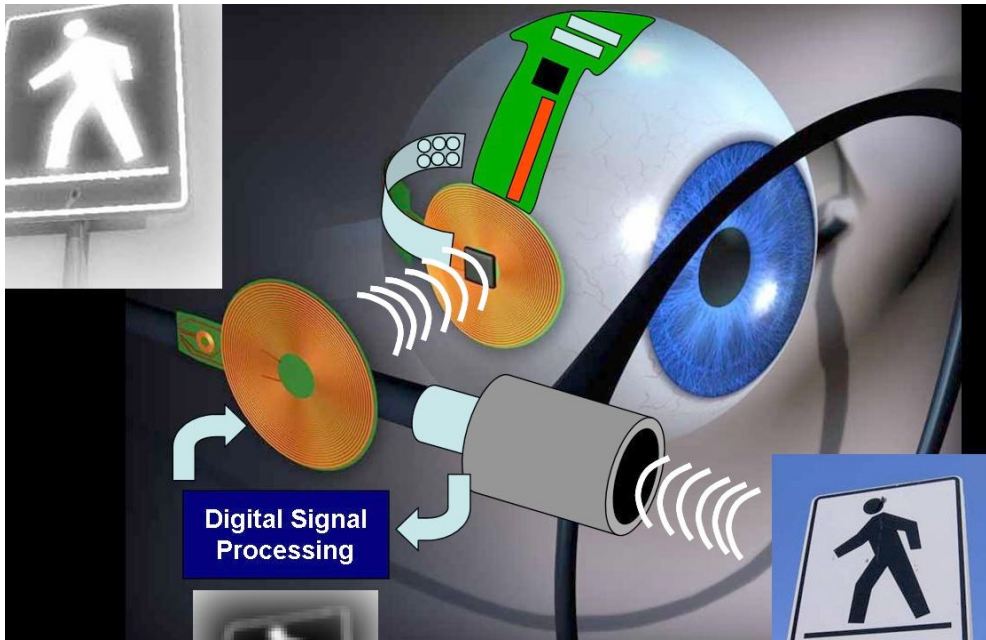
Retinal Implants

- ✓ Millions world-wide suffer severe visual impairment
 - inborn visual deficits
 - accident
 - disease
 - macular degeneration -- diabetes
 - retinitis pigmentosa
 - neovascular disease

- ✓ Must conform to surface geometry of eye

- ✓ Stimulate optic nerve

Retinal Implants



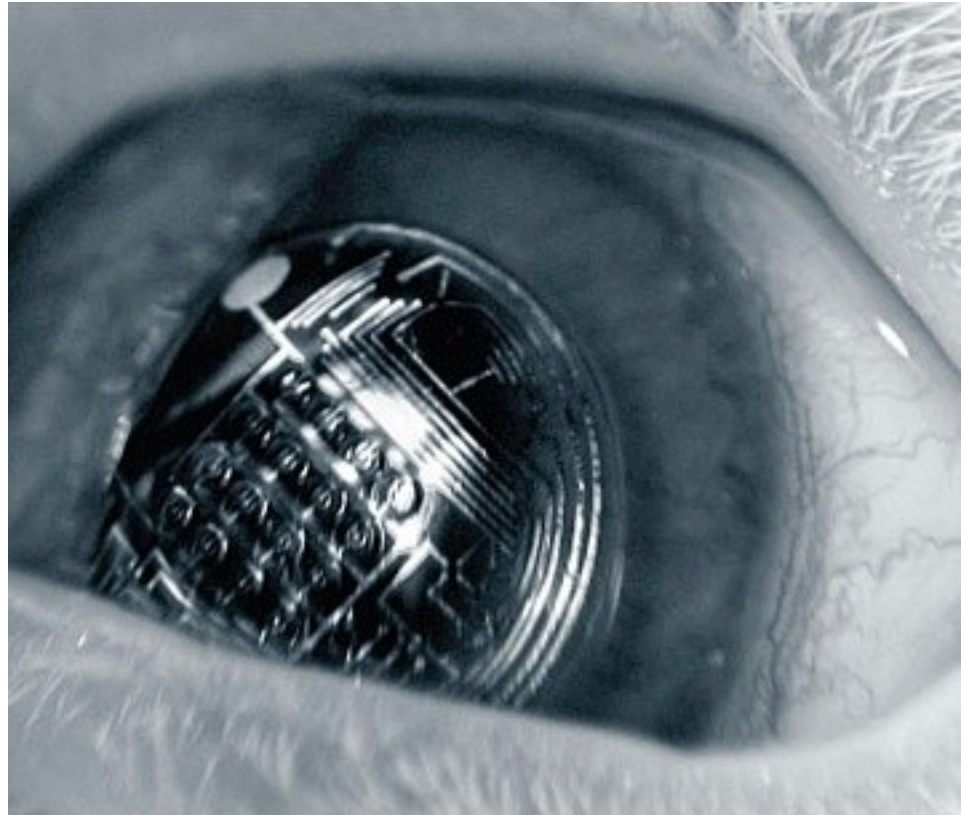
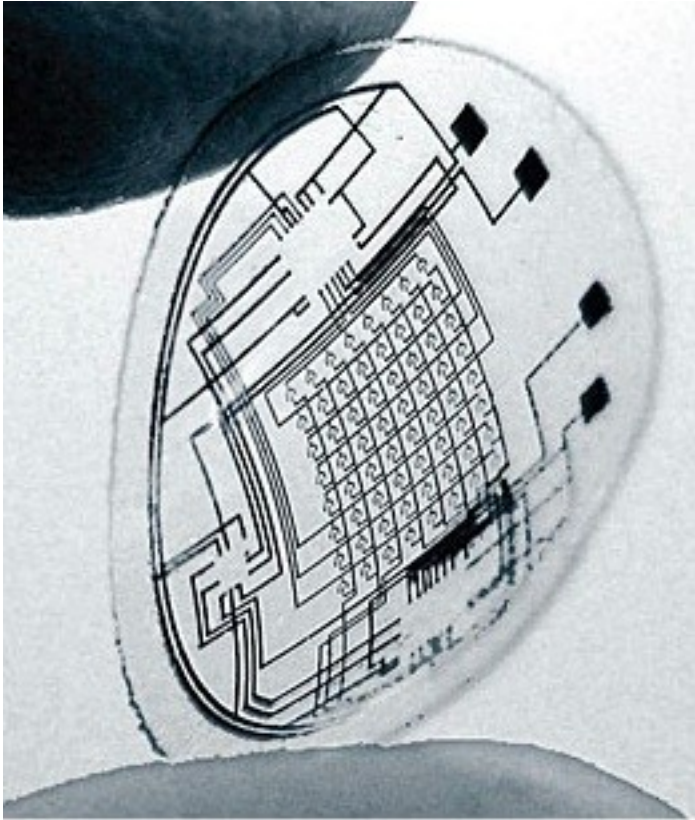
<http://www.bostonretinalimplant.org>



Futuristic Contact Lenses

- ✓ Improve vision
- ✓ Replace cornea
- ✓ Information input device

Futuristic Contact Lenses



Professor Babak A. Parviz University of Washington

Brain Function: EEG Based Systems

- ✓ Monitor electrical signals

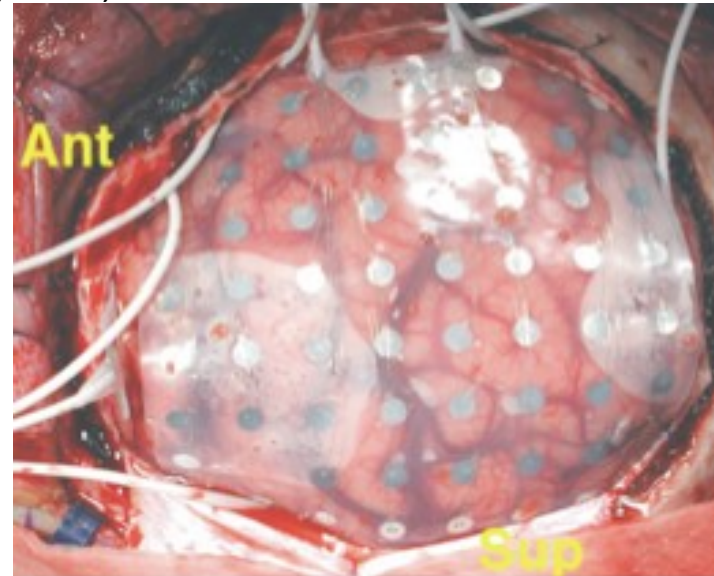
- ✓ Replace motor control
 - degenerative disease
 - traumatic injury

EKG based Brain Computer Interface

- ✓ Miniaturization
- ✓ Flexible
- ✓ More electrodes
- ✓ On-board electronics
- ✓ Improved sensitivity & spatial resolution



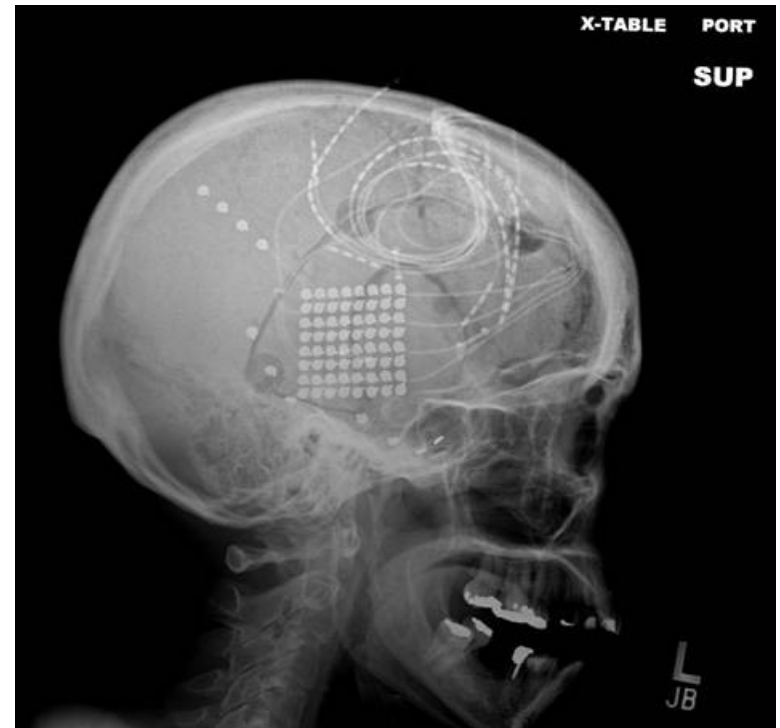
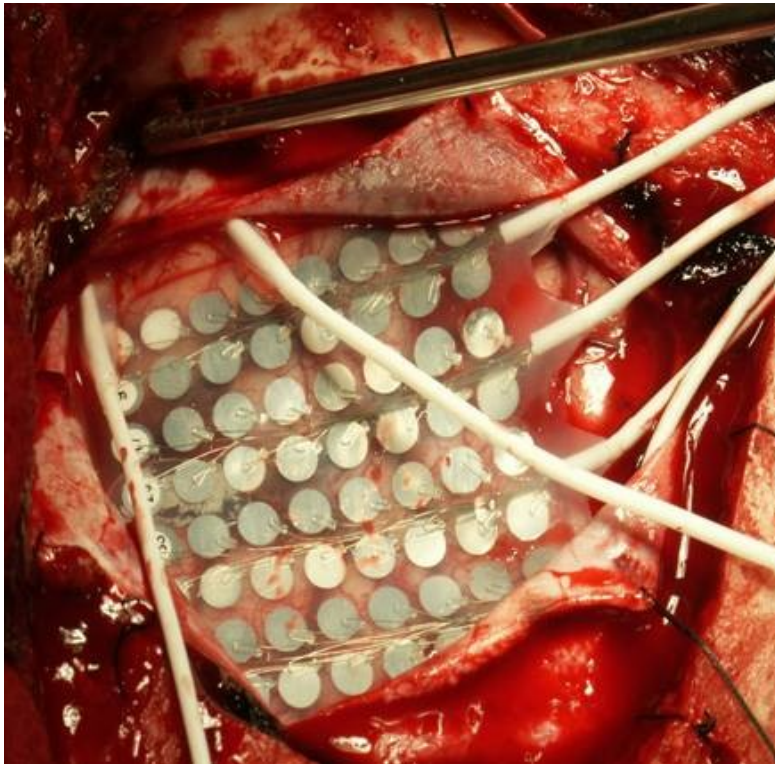
Wolpaw, et al., Wadsworth Center



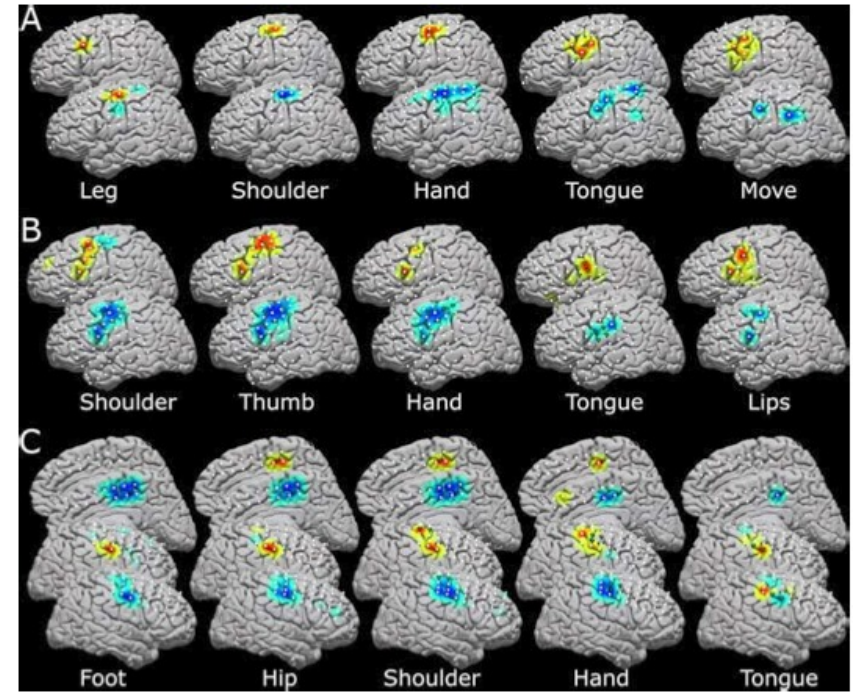
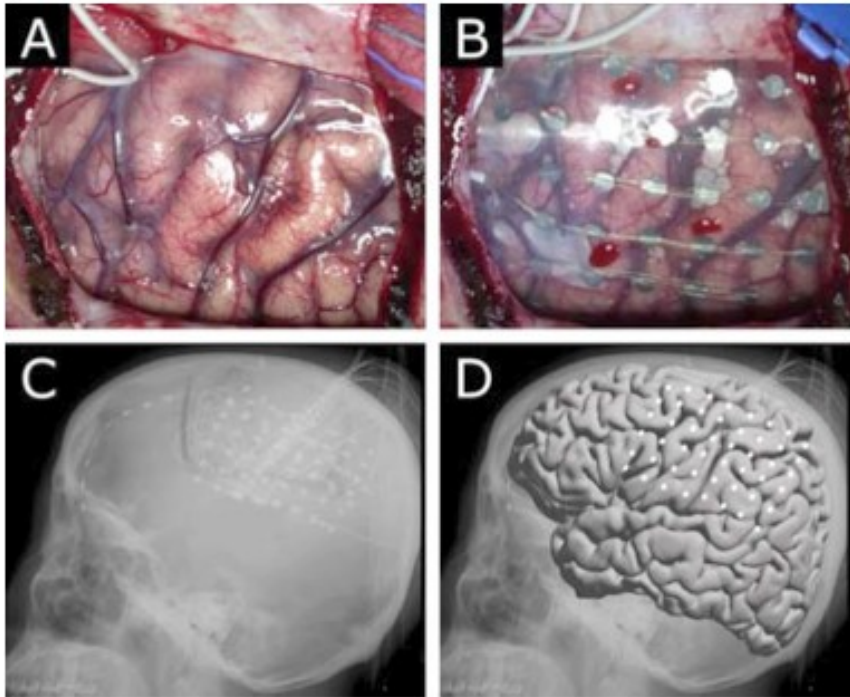
Leuthardt, et al., J. Neural Eng. 1
(2004) 63-71

Subdural Electrodes

- Clinically used for monitoring of epilepsy and treatment of chronic Deafferentiation pain



Accurate Brain Function Mapping



Miller, et al., J. Neurosci, 27, 2424-2437, 2007

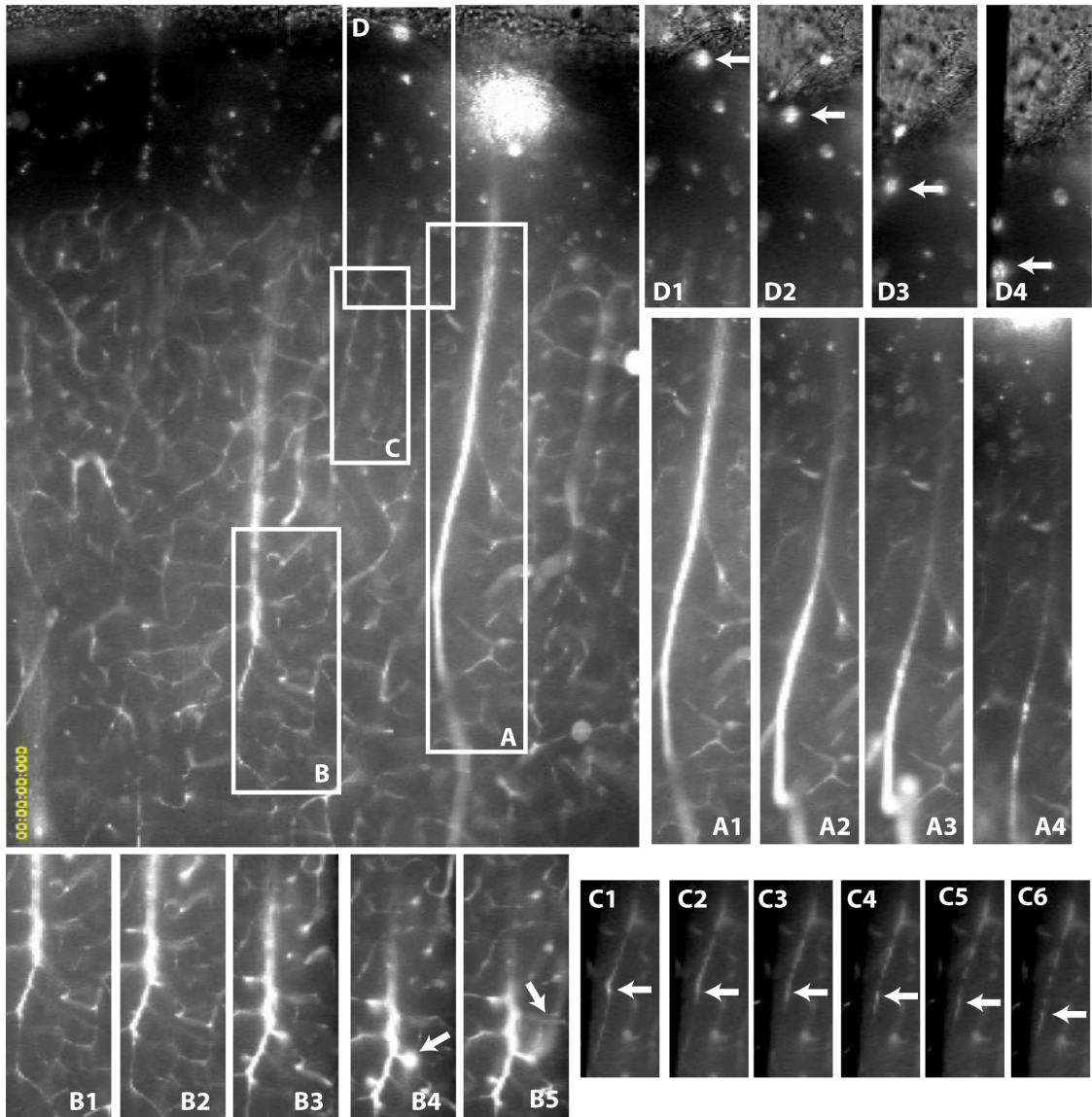
Brain Function: Penetrating Electrodes

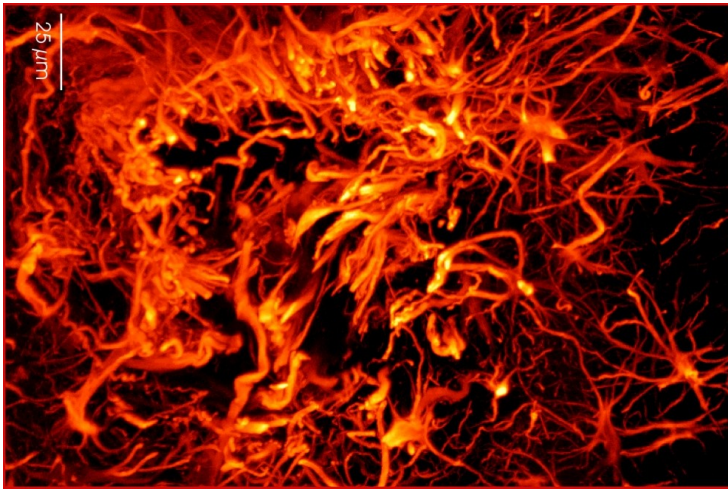
Replace motor control

- degenerative disease
- traumatic injury

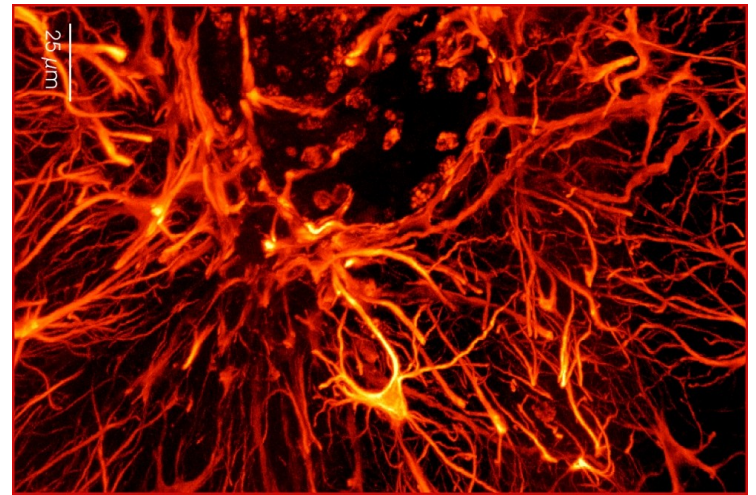
Reactive responses major problem

- proliferation of glia and microglia
- proliferation of blood vessels
- proliferation of connective tissue

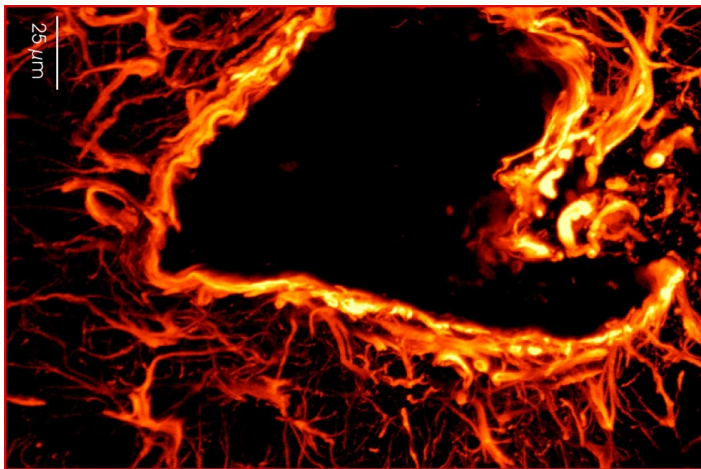




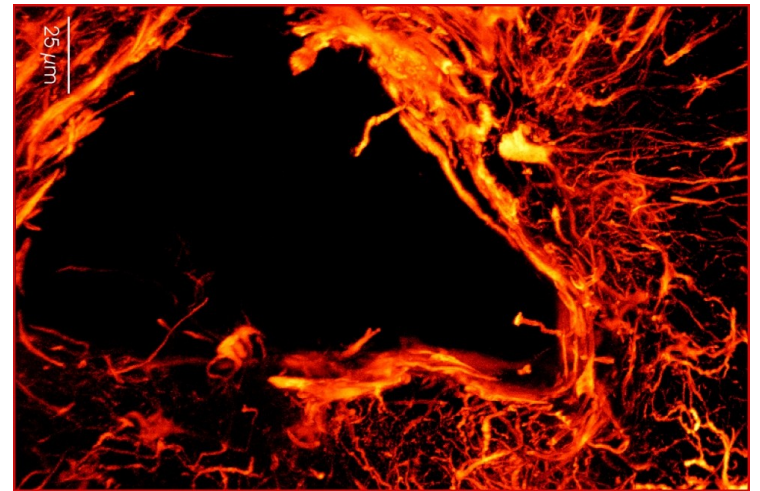
2 Weeks post insertion



4 Weeks post insertion

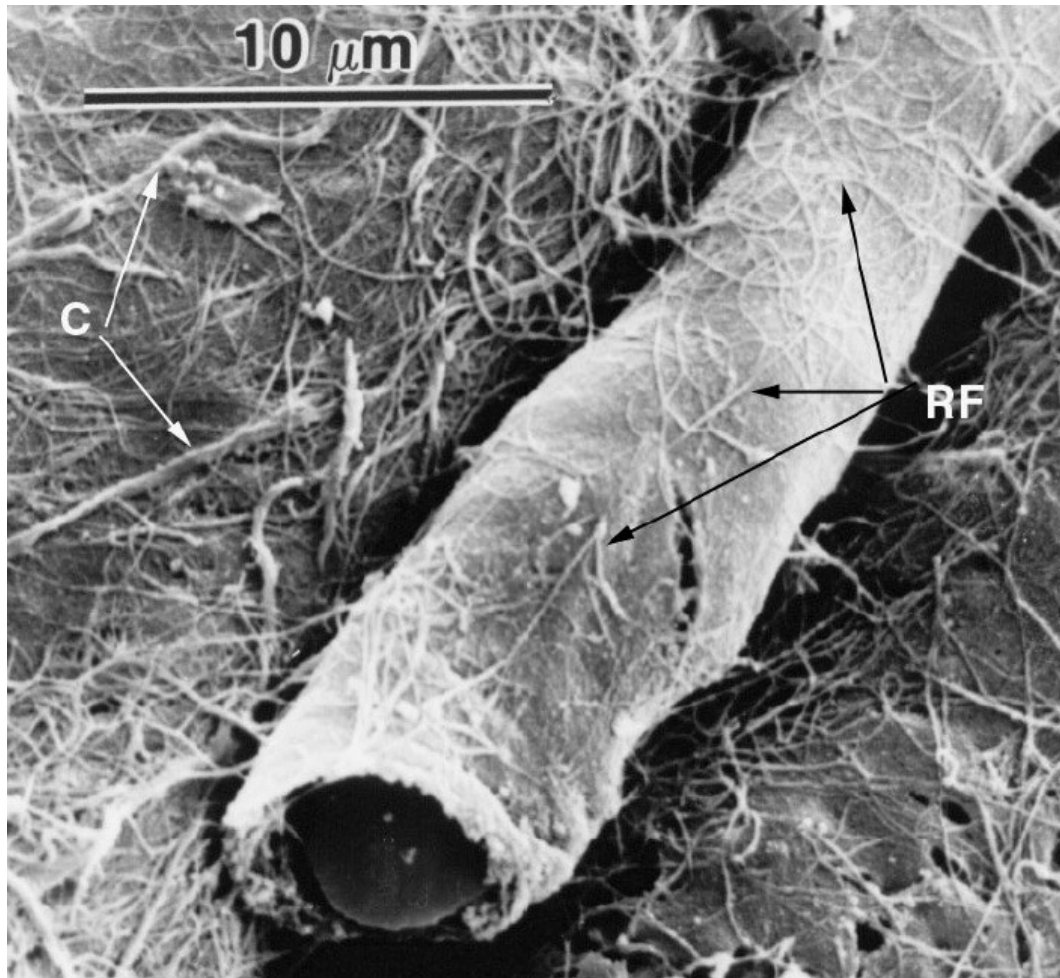


6 Weeks post insertion

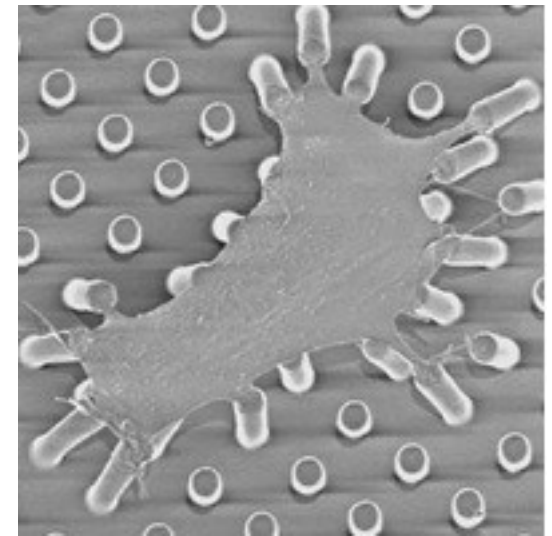


12 Weeks post insertion

Biological Surfaces



Connective tissue:
hydrogel of
fibular proteins

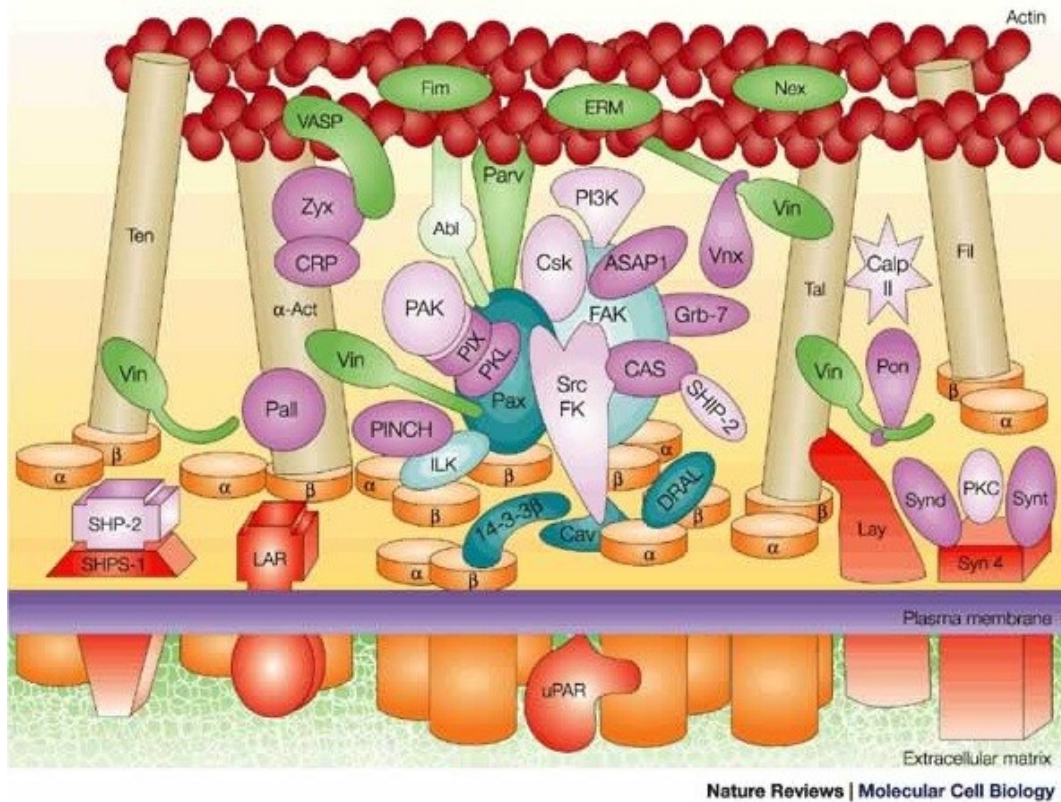


Christopher Chen University of
Pennsylvania

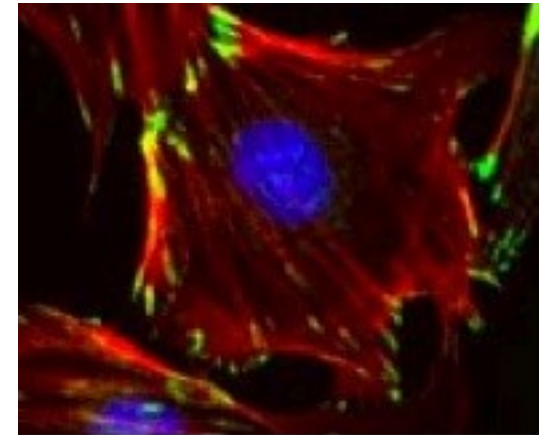
[biomed.metu.edu.tr/courses/term_papers/
OsmanBozkurt_files/image002.jpg](http://biomed.metu.edu.tr/courses/term_papers/OsmanBozkurt_files/image002.jpg)

Cell Surface Interactions

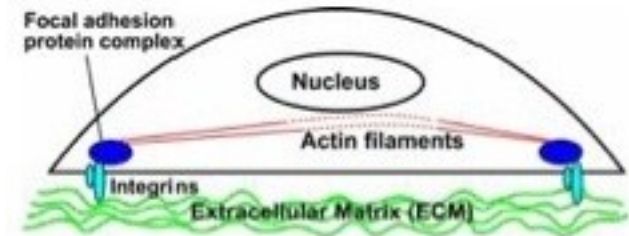
Integrins



Mechanical



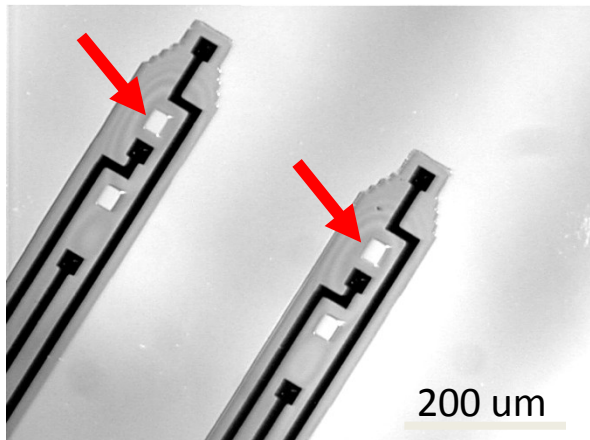
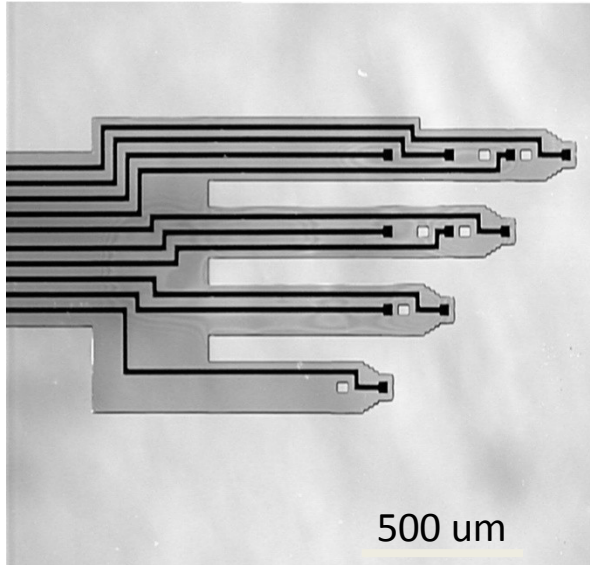
<http://biotech101.blogspot.com>



<http://biotech101.blogspot.com>

<http://www.virtuallaboratory.net/Biofundamentals/lectureNotes/AllGraphics/focalContact.jpg>

Polyimide Electrodes



‘Flexible’ Polyimide-based Intracortical Electrode Arrays with Bioactive Capability

Patrick J. Rousche (member IEEE), David Pellinen (member IEEE), David P. Pivin Jr. (member IEEE)[¶], Justin C. Williams, Rio Vetter, Daryl R. Kipke

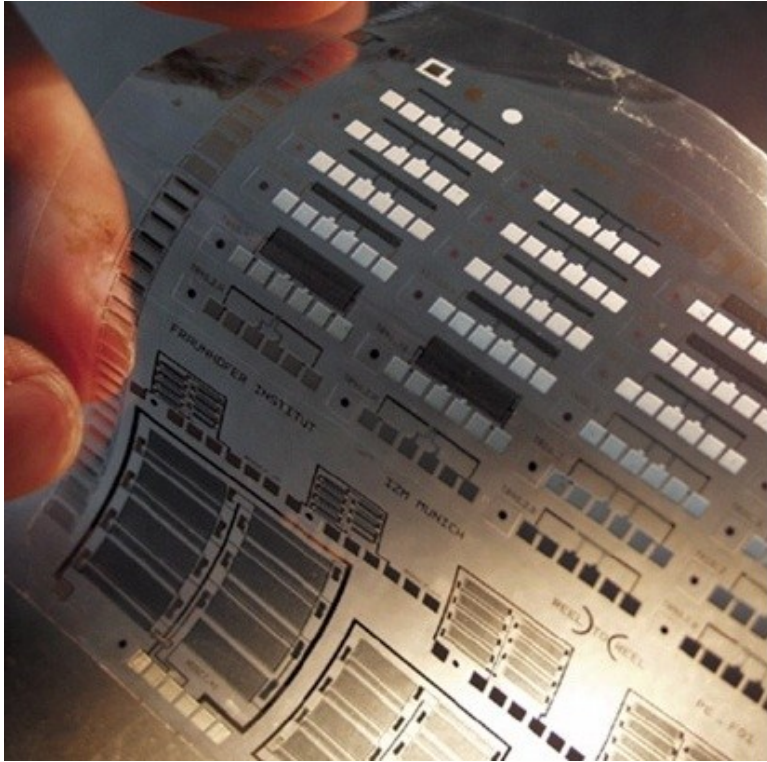
Neural Engineering Group, Bioengineering Department
[¶]Center for Solid State Electronics Research
Arizona State University
Tempe, AZ, USA 85287-6006

- Mechanically flexible
- Custom-made device shapes
- Rapid prototyping
- Ease of manufacture
- Controllable surface chemistry
- *Integrated wells for drug delivery*

Challenges for Application of FlexE

- ✓ Surface Biocompatibility
 - Non-denaturing of Biomolecules
 - Hydration
 - Non-absorbing surfaces
- ✓ Bulk Biocompatibility
 - Density & stiffness ~ that of biological tissues
 - Minimize micromotion
 - Complete integration into tissue
- ✓ Implementation of FlexE Technology
 - Engineering is basically available
 - Stretchable electronics

Flexible or Stretchable?



Sigurd Wagner
Princeton University

John Rogers
University of Illinois

Unique Challenges of Stretchable

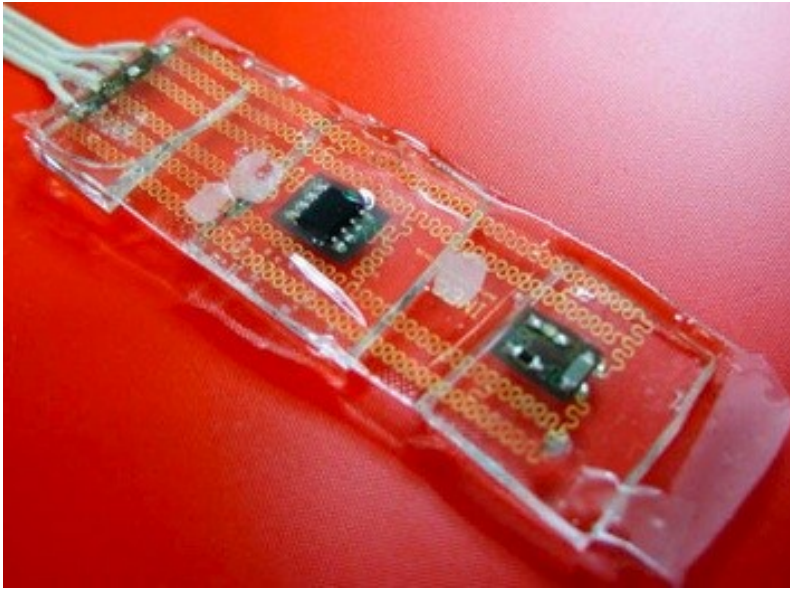
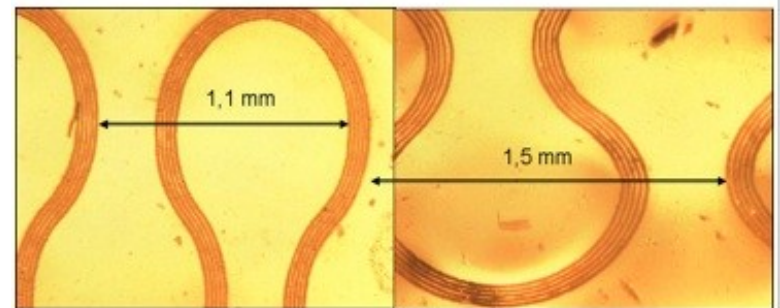


Figure 1: Elastic interconnections connecting flexible component islands



Centre for Microsystems Technology, Universiteit Gent



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