mc10

High Performance Conformal Electronics

Electronics Anywhere: Conformal, Stretchable Electronics Using Novel Mechanics & Conventional Materials

2011 FLEX
Presented by FlexTech Alliance
February 7-10, 2011
10th ANNUAL

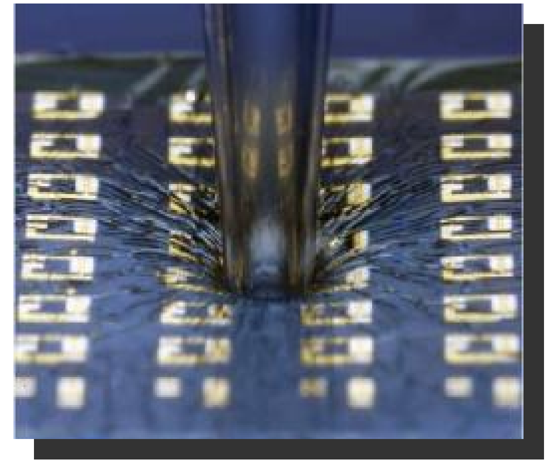
MC10 Overview

Summary

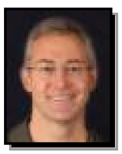
•Based in Cambridge, MA, USA

•Backed by North Bridge, Osage, Terawatt

•Strong advisory team

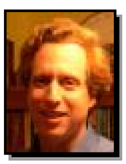


Management Team & Key People



David A. Icke, CEO
Advanced Electron Beams, Teradyne, KLA-Tencor, Cypress Semiconductor. BS Stanford; MBA Harvard

Jeffrey Carbeck, PhD, CTO
Arsenal Medical, Nanoterra
Asst. Prof. Chemical Engineering, Princeton
BS Michigan, PhD MIT, Post Doc Harvard



Kevin Dowling, PhD, VP of R&D
Philips/Color Kinetics, PRI Automation, Robotics Institute
BS, MS, PhD Carnegie Mellon

Ben Schlatka, VP of Business Development
IBM Microelectronics, Nantero
BBA UMass, Amherst; MBA Harvard

John A. Rogers, PhD, Co-Founder
University of Illinois Urbana Champaign,
Depts. of Materials Science & Engineering, Electrical & Computer Engineering, and Chemistry
Founded: Active Impulse Systems

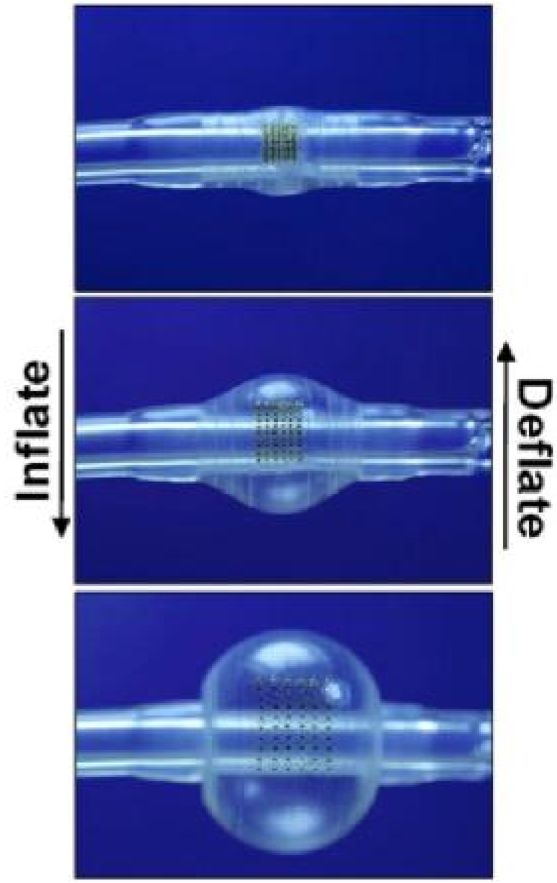
George M. Whitesides, PhD, Co-Founder
Harvard University, Dept. of Chemistry & Chemical Biology.
Founded: Genzyme, Geltex, Surface Logix, Nanoterra

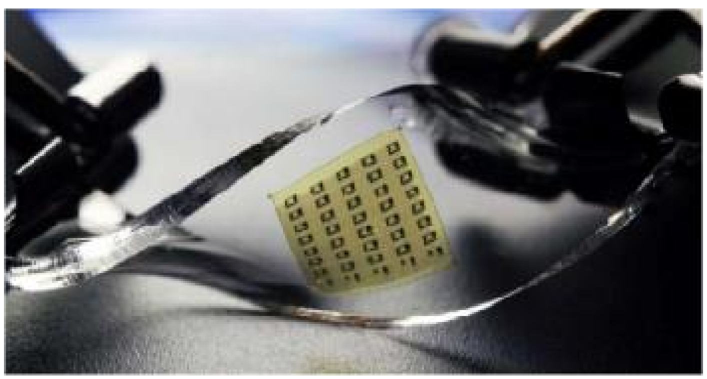
Carmichael S. Roberts, PhD, Chairman
North Bridge Venture Partners, Partner.
Founded: Arsenal Biomedical, Surface Logix, Inc

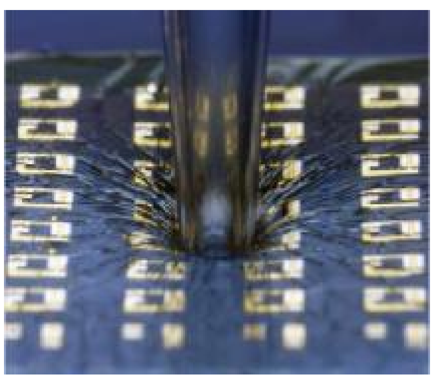
John M. Deutch, PhD
Institute Professor at MIT, Dept. of Chemistry,
Member Defense Science Board, former Dir. of CIA

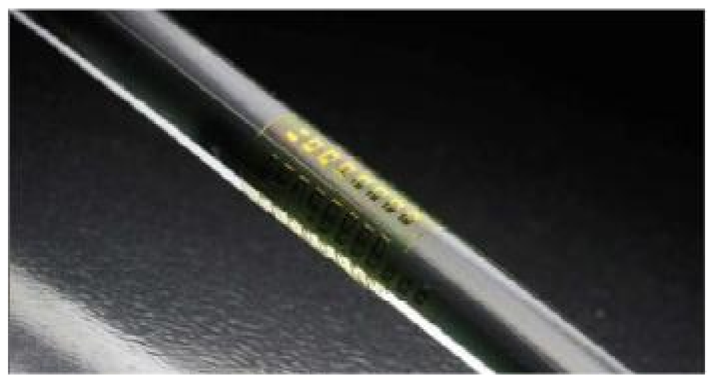
New Shapes with High Performance

- Problem:
  - Conventional integrated circuits (ICs) are rigid, brittle and planar
  - State-of-the-Art flexible circuits lack performance and reliability
- Solution:
  - Stretch, twist, expand, deploy with conventional IC performance, enabling breakthrough products and applications







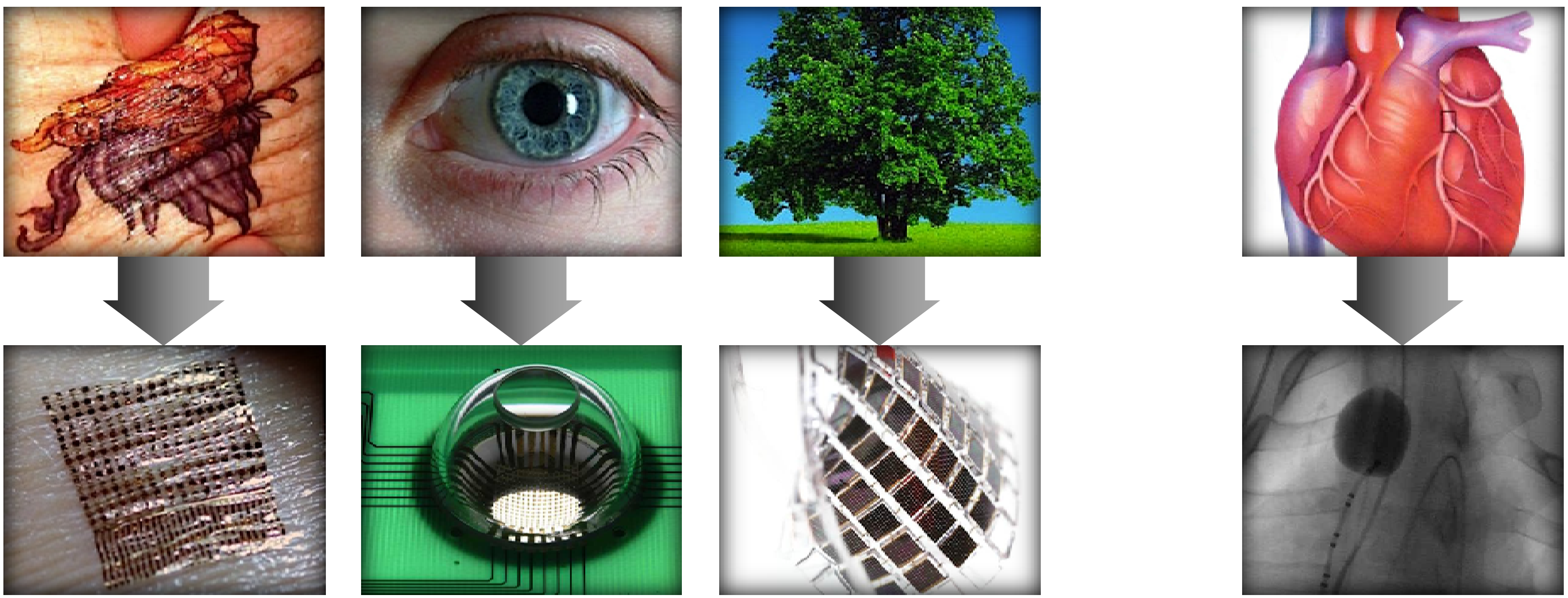


Conformal Electronics Use Cases

Synthetic Sensing & Interventional Circuits

Mimic Nature Through Revolutionary Shapes, Sizes, & Configurations

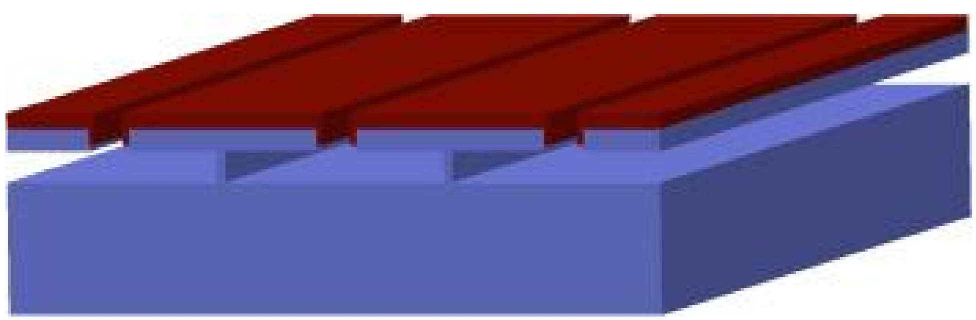
Diagnose and Influence Tissue Functions with High Spatial & Temporal Resolution

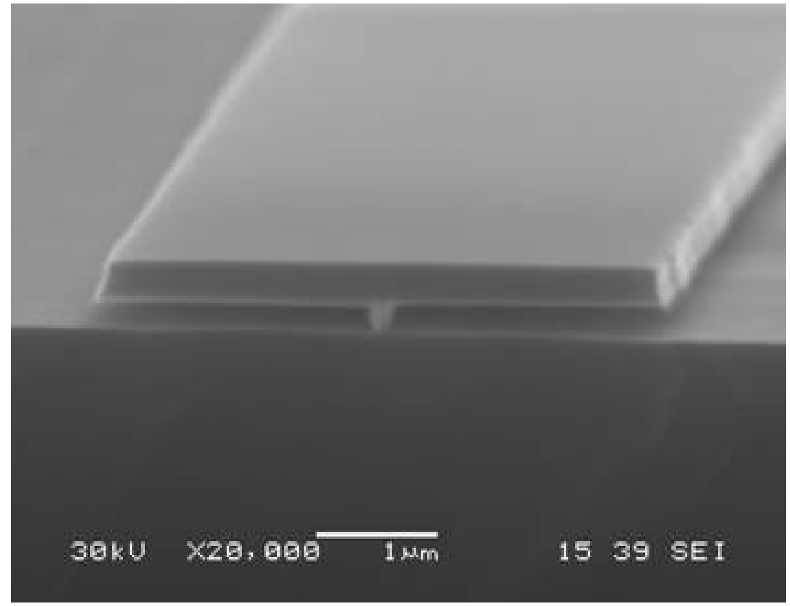


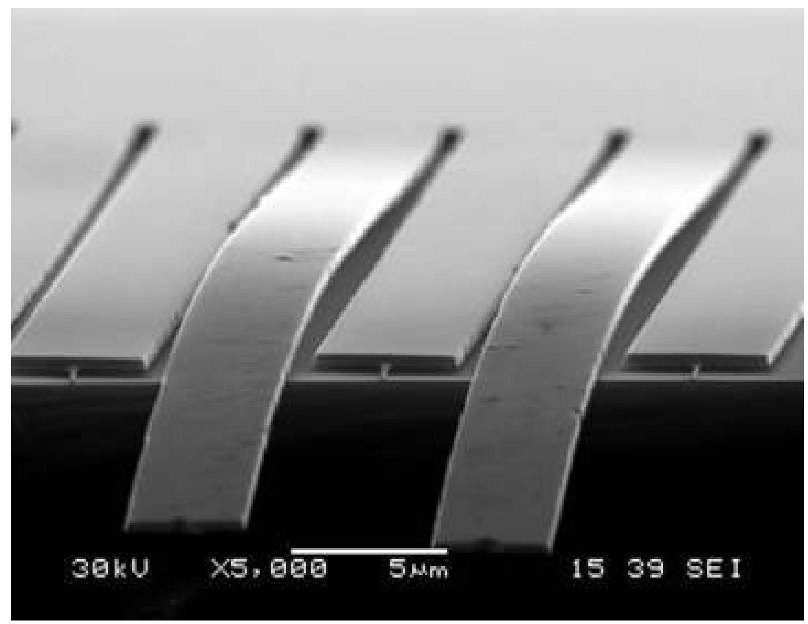
Flexible Nanoribbons of Silicon

etch trenches

protect sidewalls;
etch undercuts

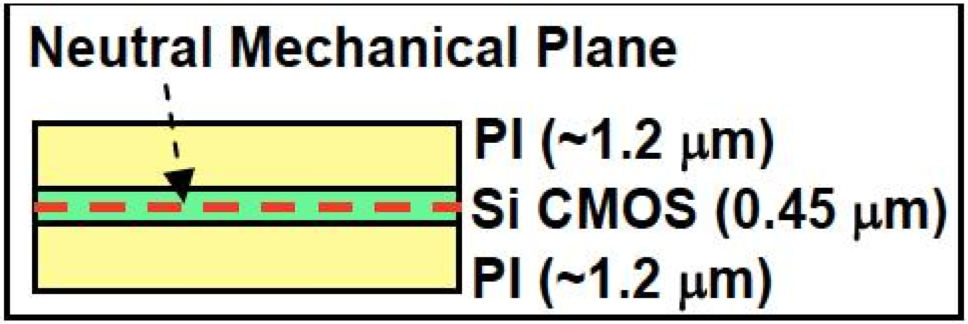


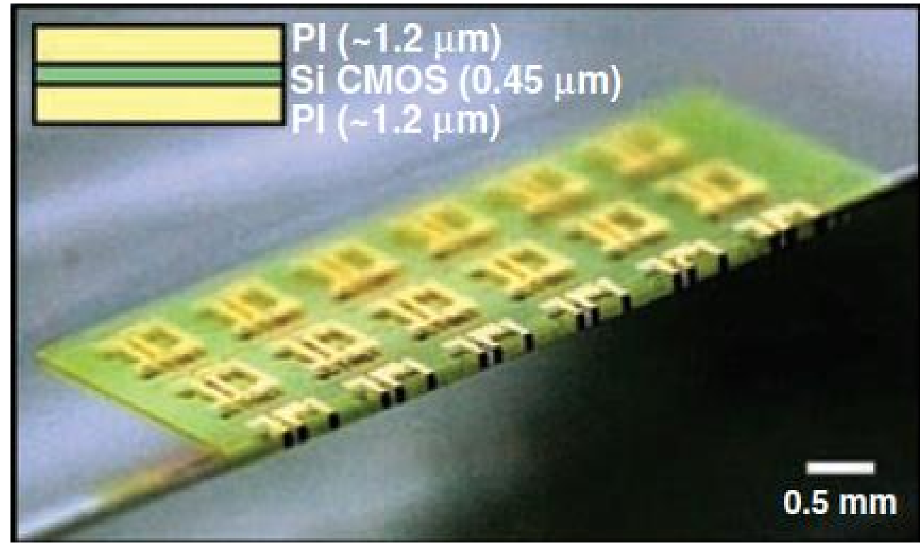


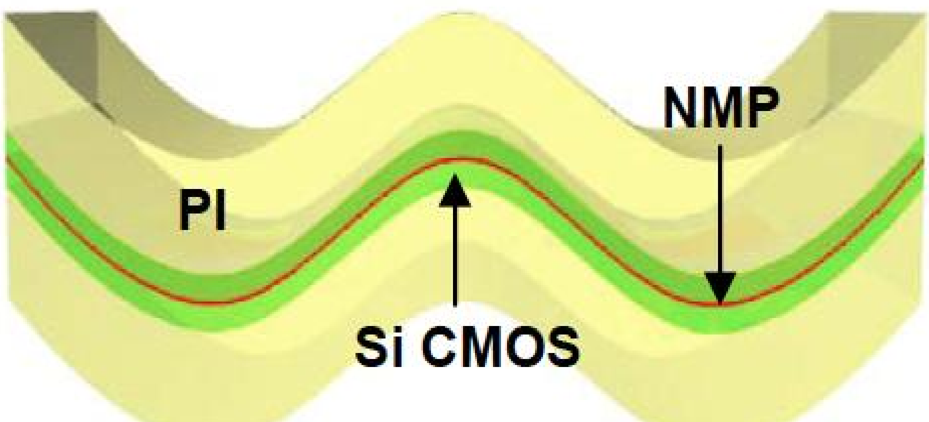


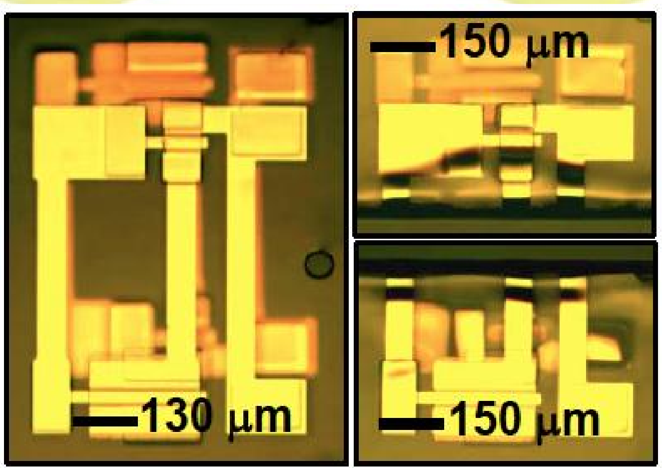
Adv. Func. Mater. (2007). *Appl. Phys. Lett* (2006)

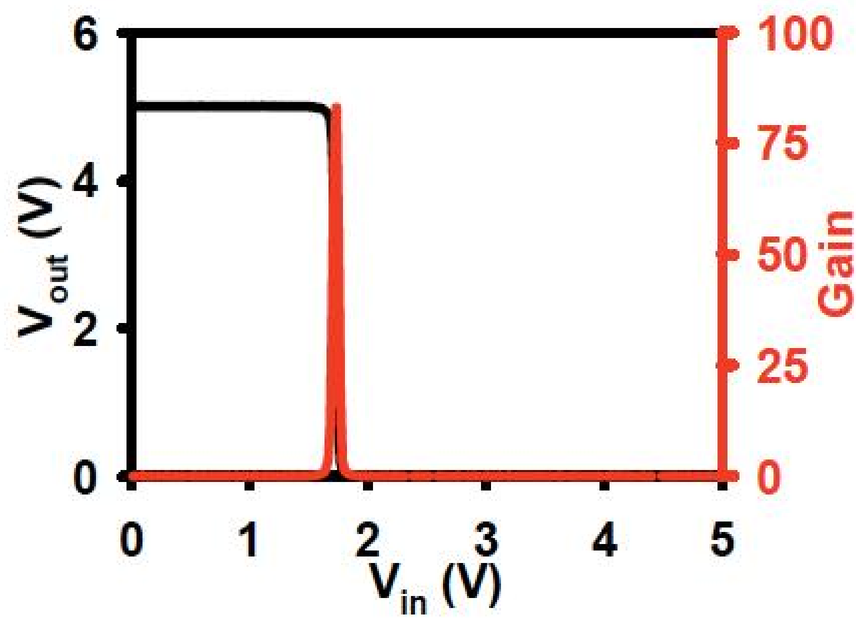
Minimize Strain in Semiconductors: Flex





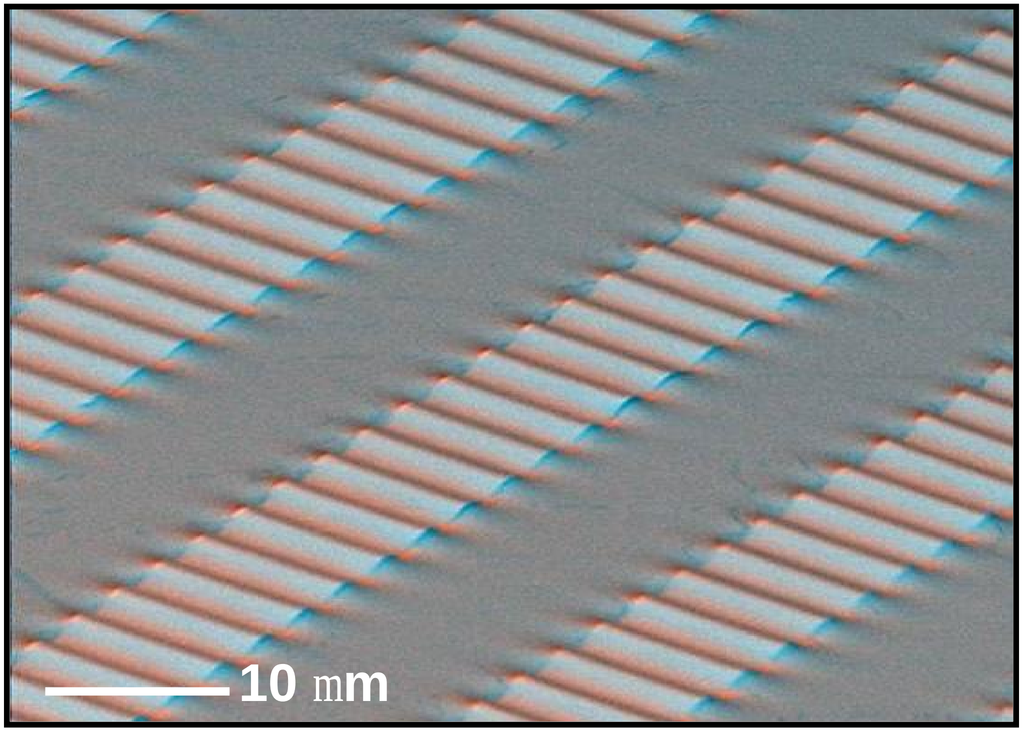




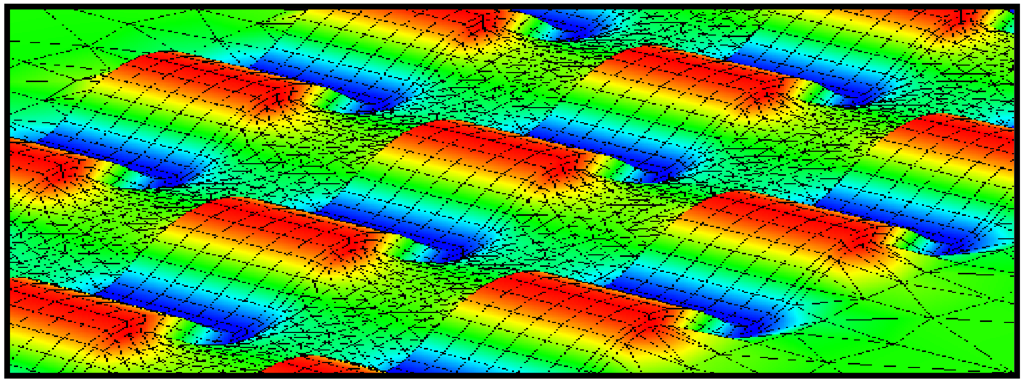


Stretchable, 'Wavy' Nanoribbons of Si on Rubber

Materials



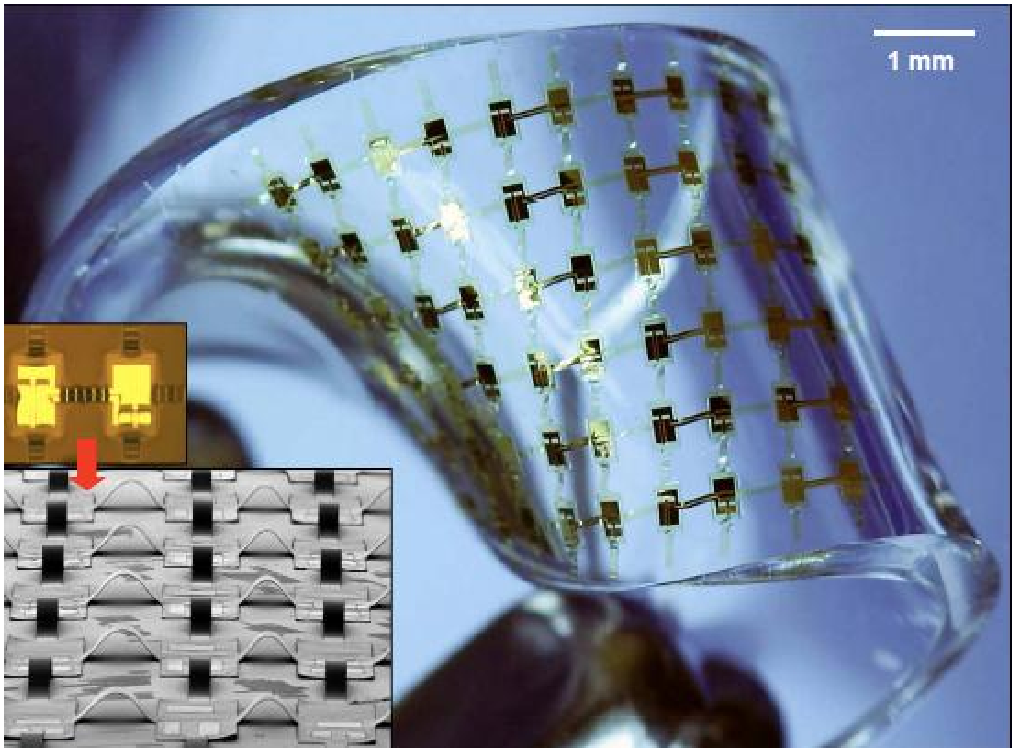
Mechanics

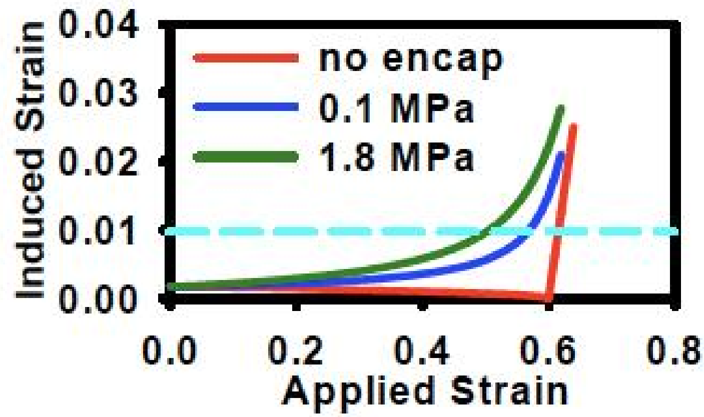


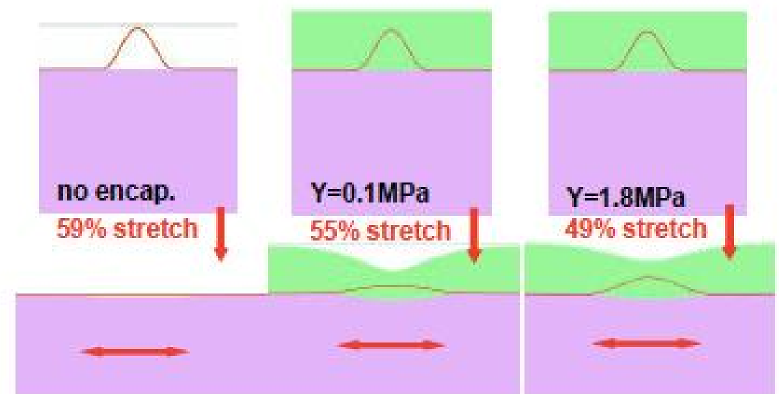
'Accordion' Physics

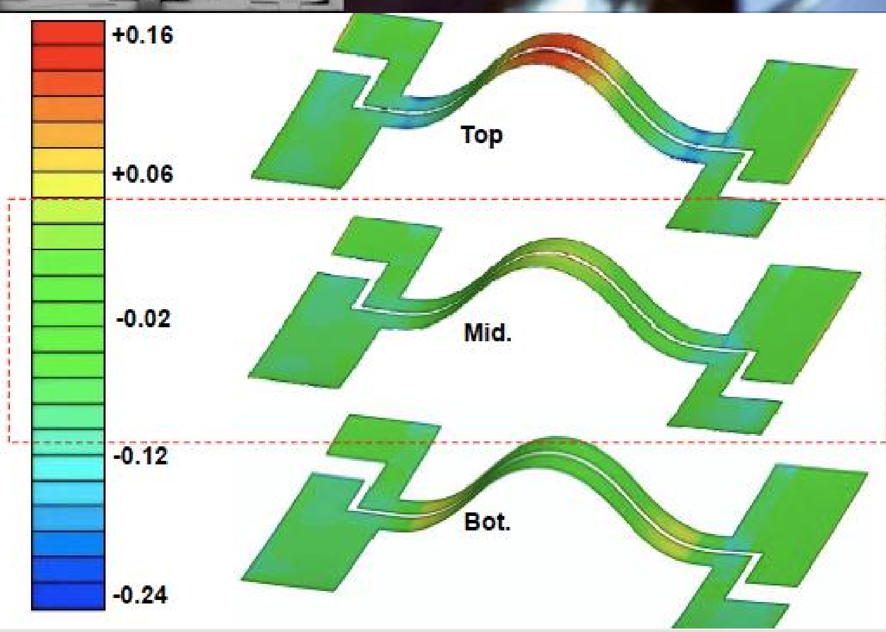
Science (2006)
PNAS (2007).

Minimize Strain in Semiconductors: Stretch





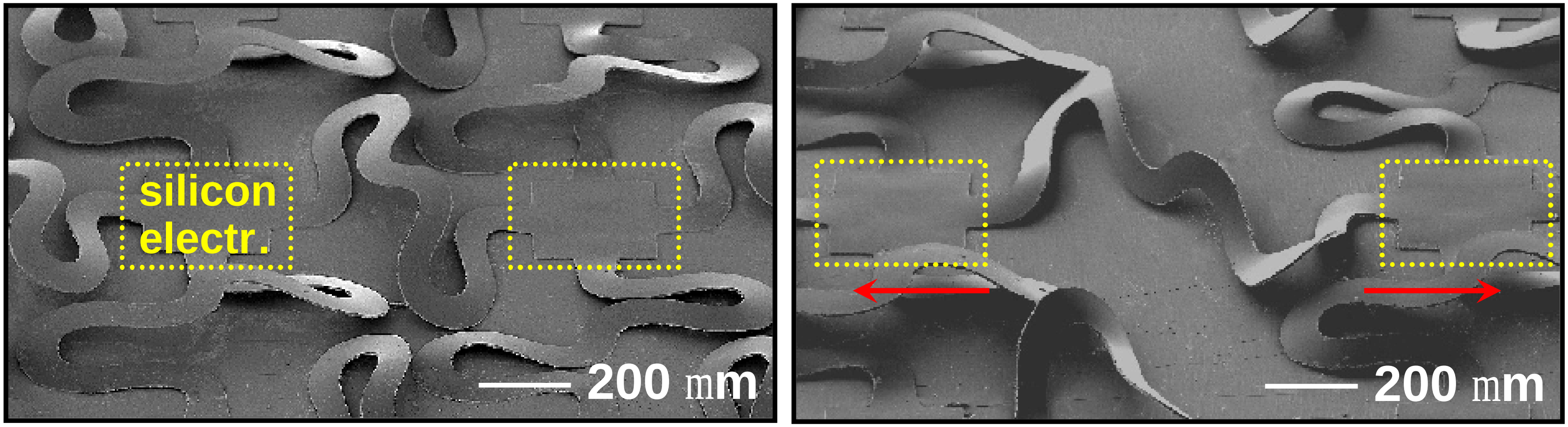




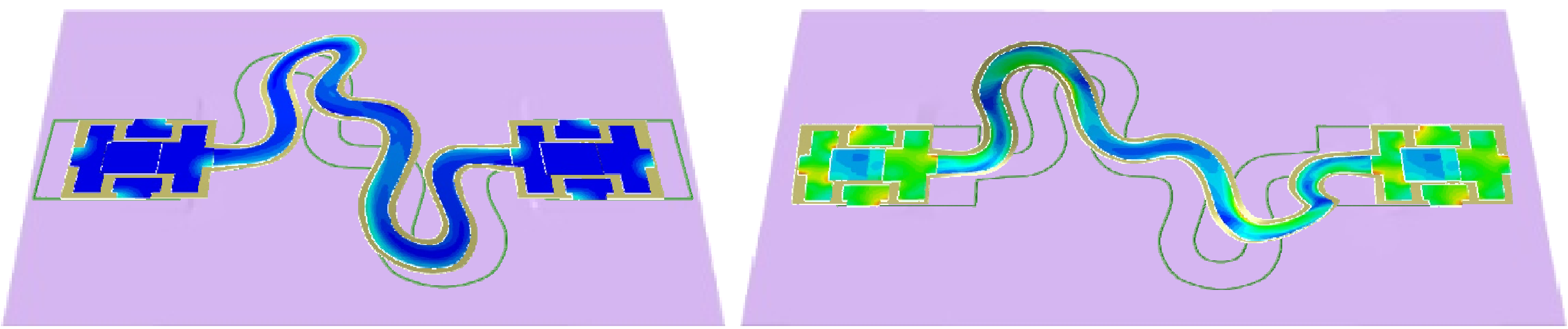
Max strain (70% strain)
metal bridge ~ 0.2%
silicon island~ 0.15%

Serpentine Mesh Interconnects

Released ←- - - - - - - - - - - -→ Stretched (60%)



Released ←- - - - - - - - - - - -→ Stretched (60%)

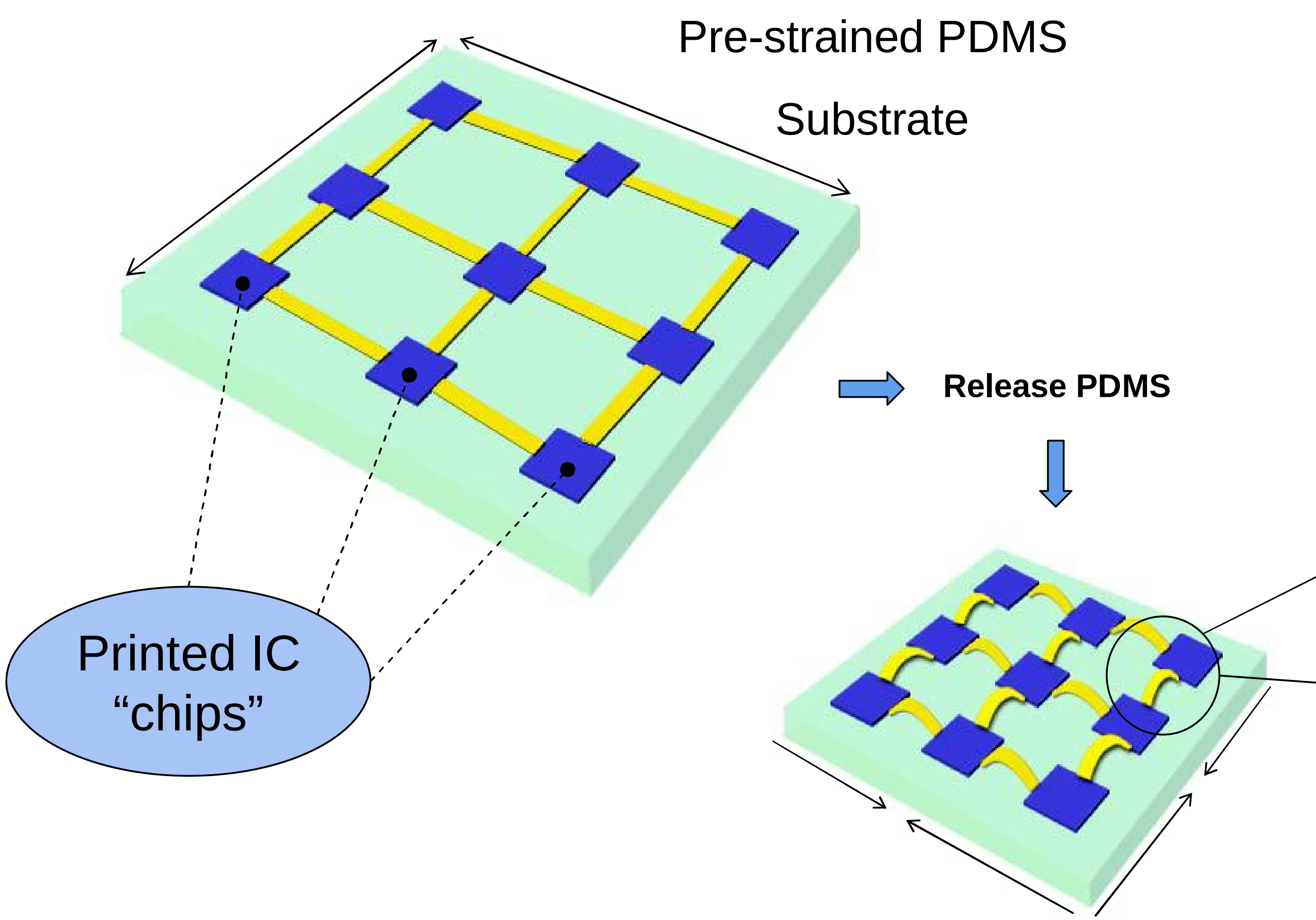


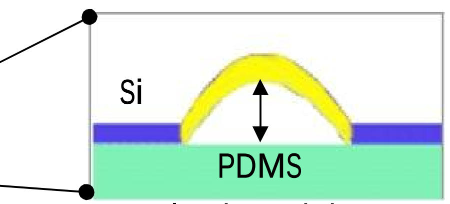
~20 % prestrain

lature Materials, (2010)

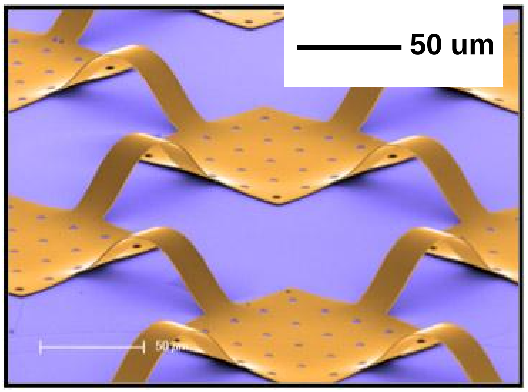
Stretchability

Devices have flexible interconnects and are positioned in "neutral mechanical plane" to limit strain on active circuit components





Delaminated due to weak bond

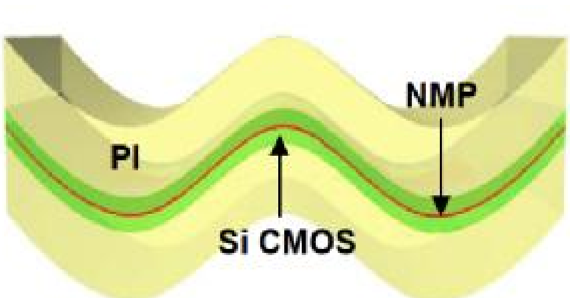


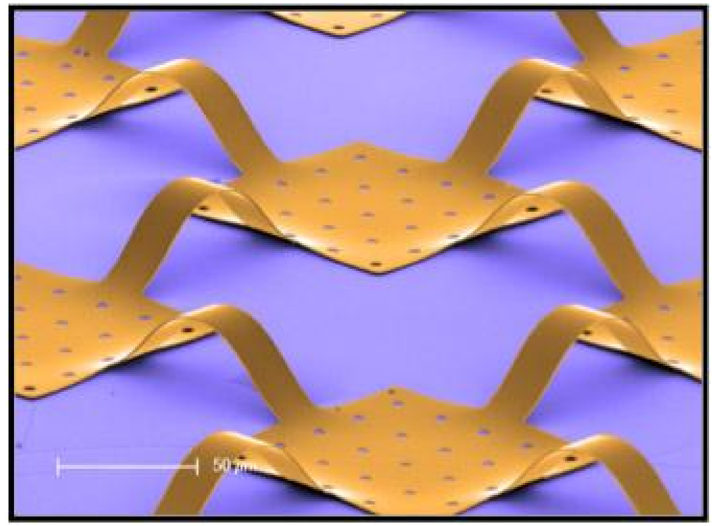
SEM Image
(colors: gold=Si; blue=plastic)

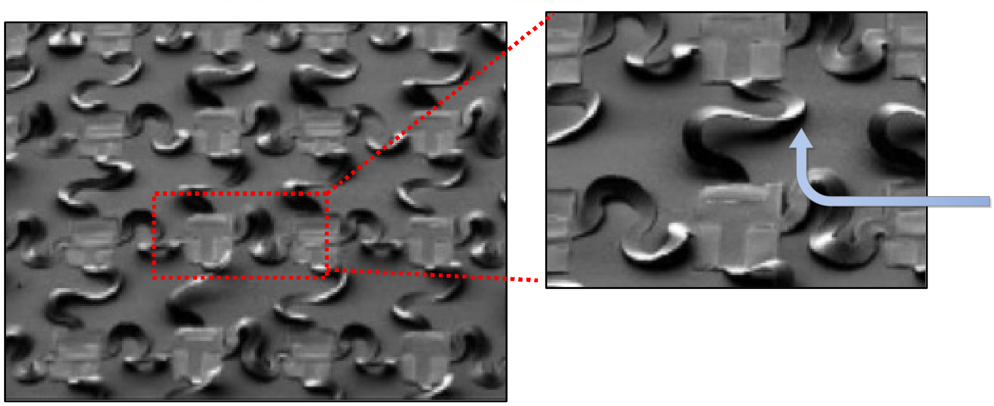
MC10 Technology: Key Features

MC10 Technology:

- Is compatible with conventional foundries to take advantage of
  - High performance (> GHz)
  - Low cost and high yield







Key Platform Features:

- Ultrathin, high performance electronics
- Proprietary interconnect designs
- Conformal polymeric substrates

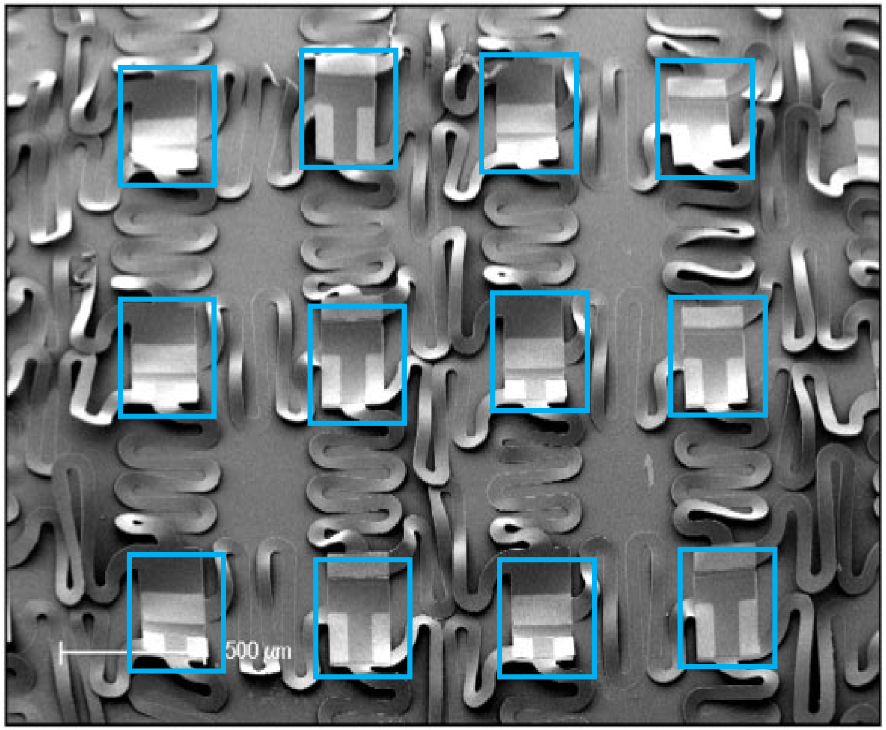
Distributed network of electronics can undergo significant folding, bending and stretching without sacrificing performance

Stretchy IC Arrays

Easy to Integrate Heterogeneous Devices & Materials

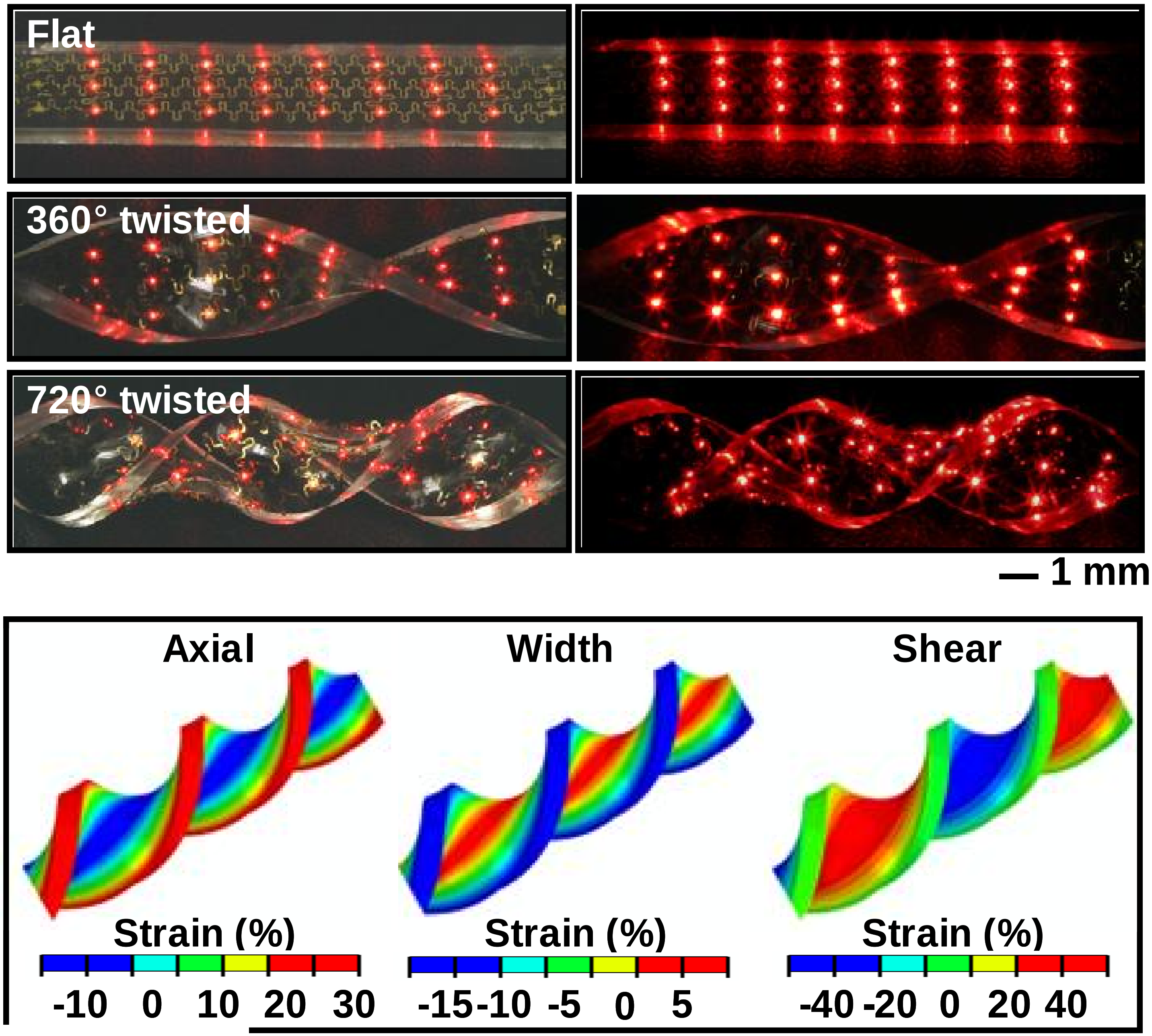
Integrated Arrays of Sensors and Control Electronics:

1. Electrodes
2. Photodiodes
3. Thermocouples
4. Pressure/contact
5. LEDs
6. Photovoltaics



A multitude of sensors can be integrated with control electronics such as multiplexors, amplifiers, and radios

μ-LEDs on a Rubber Band



lature Materials, (2010)

MC10 Applications Sweet Spot

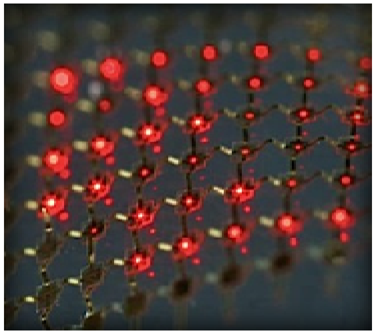
MC10 targets applications that require:

- True 3D conformality
  - Stretching or bending in different directions
- High quality measurements
  - High spatial or temporal resolution, low noise
- High value of information
- Integration into a dynamic or moving system
- Fitting into space-constrained areas
- A high degree of ruggedness and reliability
- Light weight components

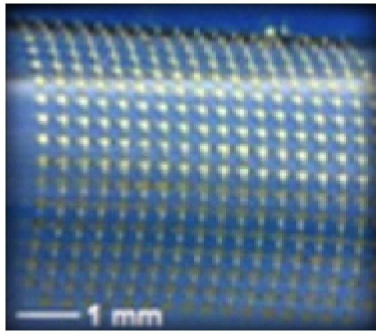
The more that apply, the stronger fit with MC10 Technology

Conformal Electronics Applications

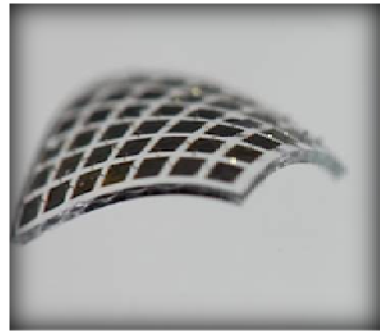
New Applications & Form Factors



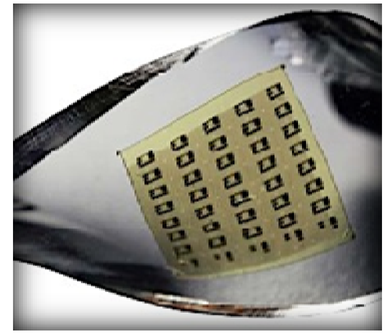
LED Array



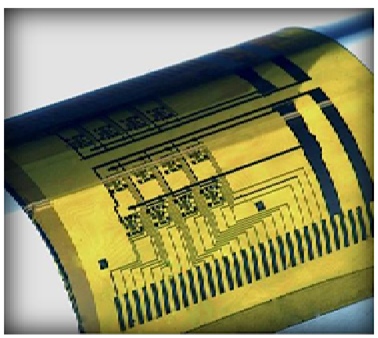
Tactile Sensor



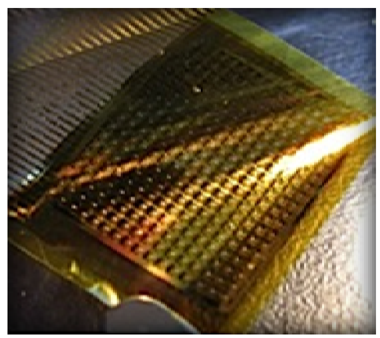
Solar Array



Wireless Radio



Strain Gauge



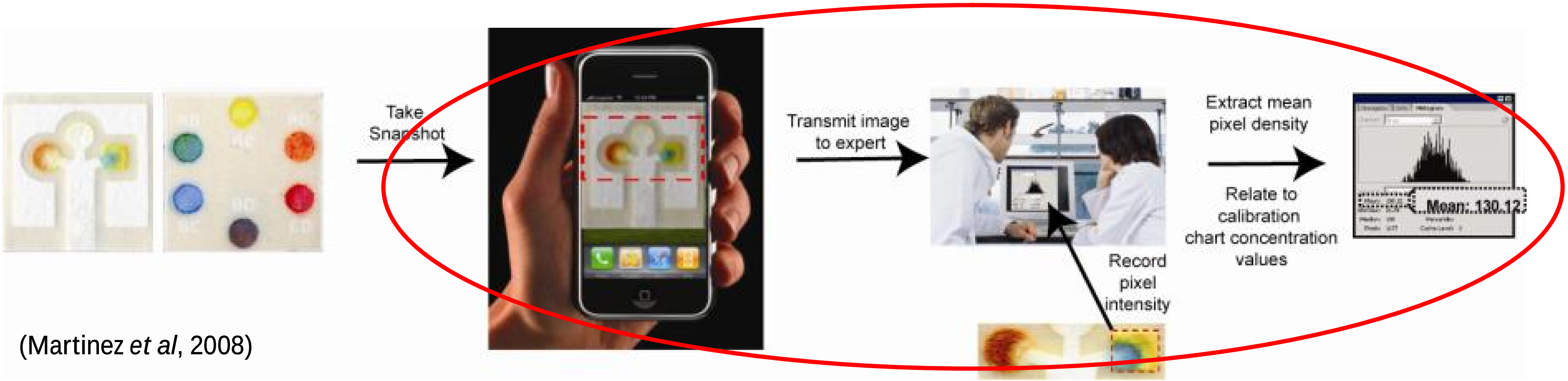
Neural Mapping

Curved Imager

Wide Array of Demonstrated Product Possibilities

Paper Diagnostics Today

MC10 paper electronics provide new possibilities for high sensitivity, low cost diagnostics, without the need for external readers



(Martinez *et al*, 2008)

Challenge:

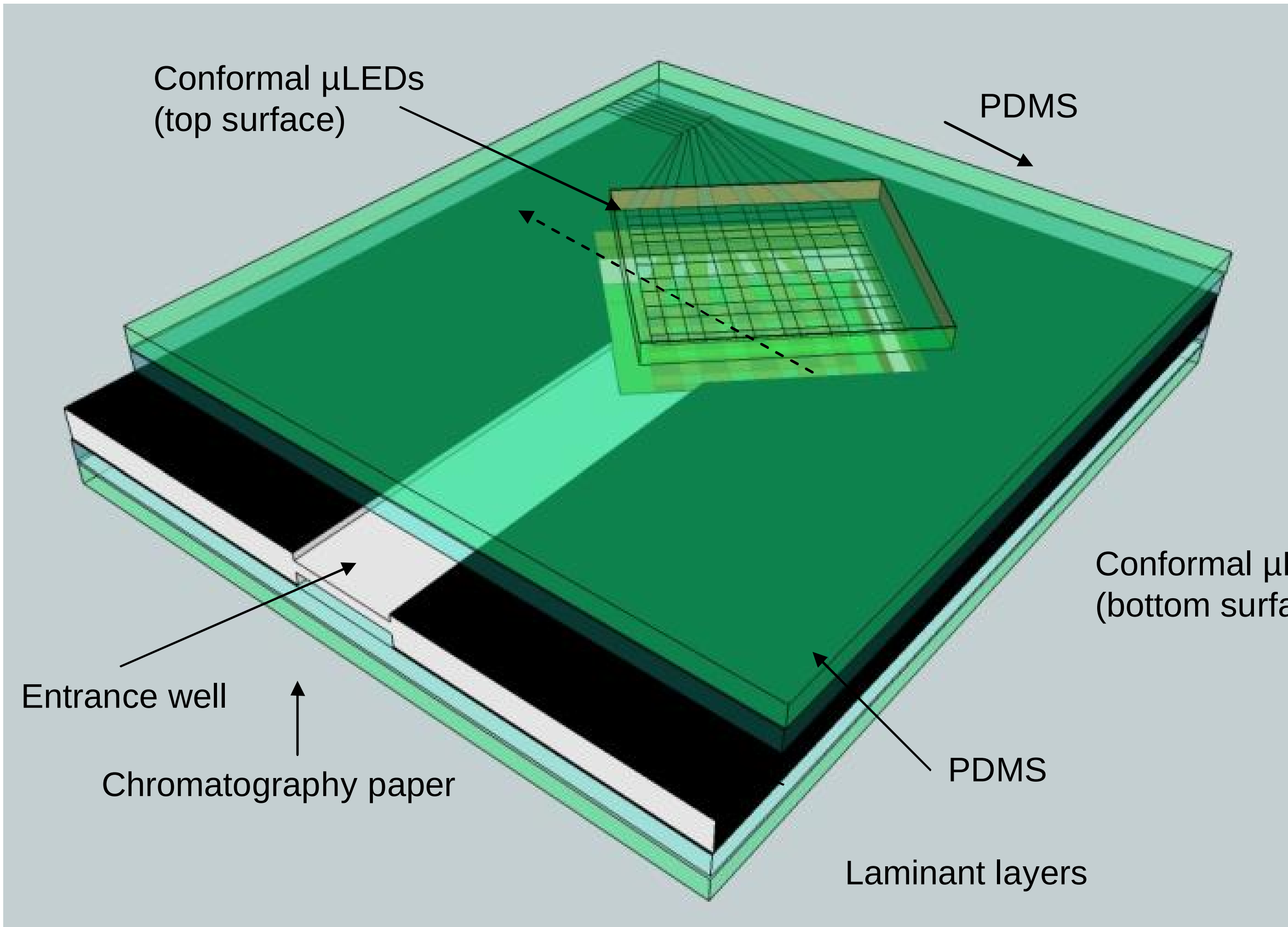
- Paper microfluidics require additional expensive equipment for quantitative analysis
- No solution currently exists for signal detection and analysis on-board a disposable device

Solution:

- Replace cell phones with stretchable integrated circuits patterned directly on paper diagnostics device

PaperDx Analysis Tomorrow…

CMOS electronics and LEDs have been demonstrated on flexible, stretchable substrates like paper creating new opportunities in diagnostics



Low Profile Wearable Electronics

Ultrathin “tattoo like” electronics possible

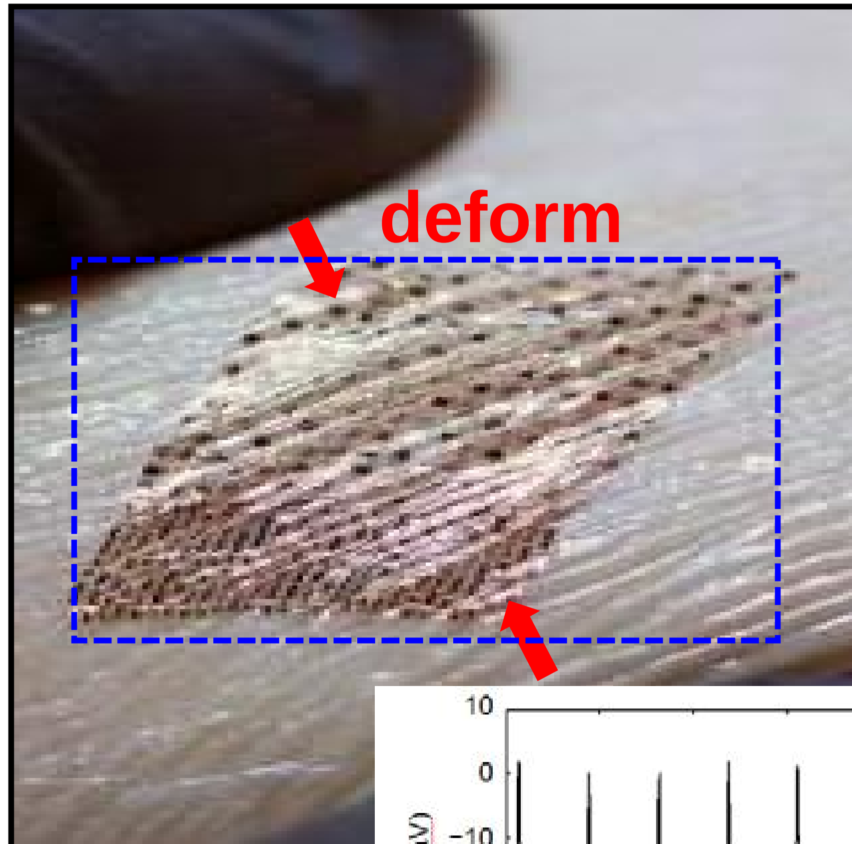
- 50um thickness = Extremely low profile
- Conformal
- Engineered to match the modulus of the skin for improved adhesion
- Capable of bending and stretching while maintaining electronic performance
- Battery-less design points possible

Results in high performance, light weight electronic stickers that can be worn on the body

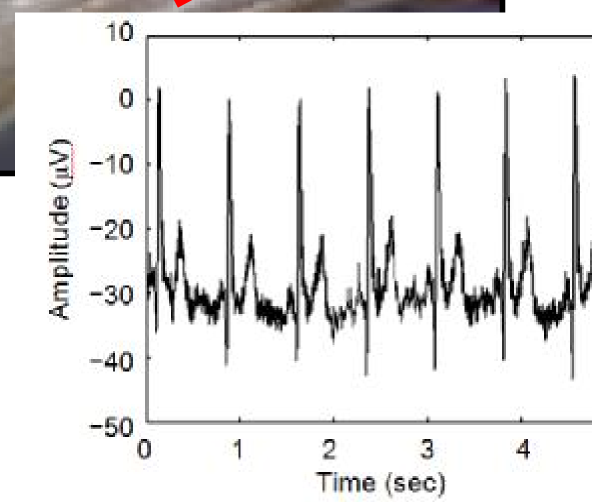
Skin-like, Bio-Integrated Electronics

Temporary Tattoo

Electronics



EKG



w/ UIUC, unpublished

Medical Device Applications

Current Medical Devices Consist of:

Optimized Materials : Biocompatible and Compliant

Engineered Mechanics : Precise Steering, Structural Integrity

Where are the electronics and feedback systems?

The Body is Soft and Compliant. Traditional Electronics are Not.

MC10 Inc.

Next Generation Medical Devices

Greater Performance
Better Signal Quality
Sophisticated Feedback

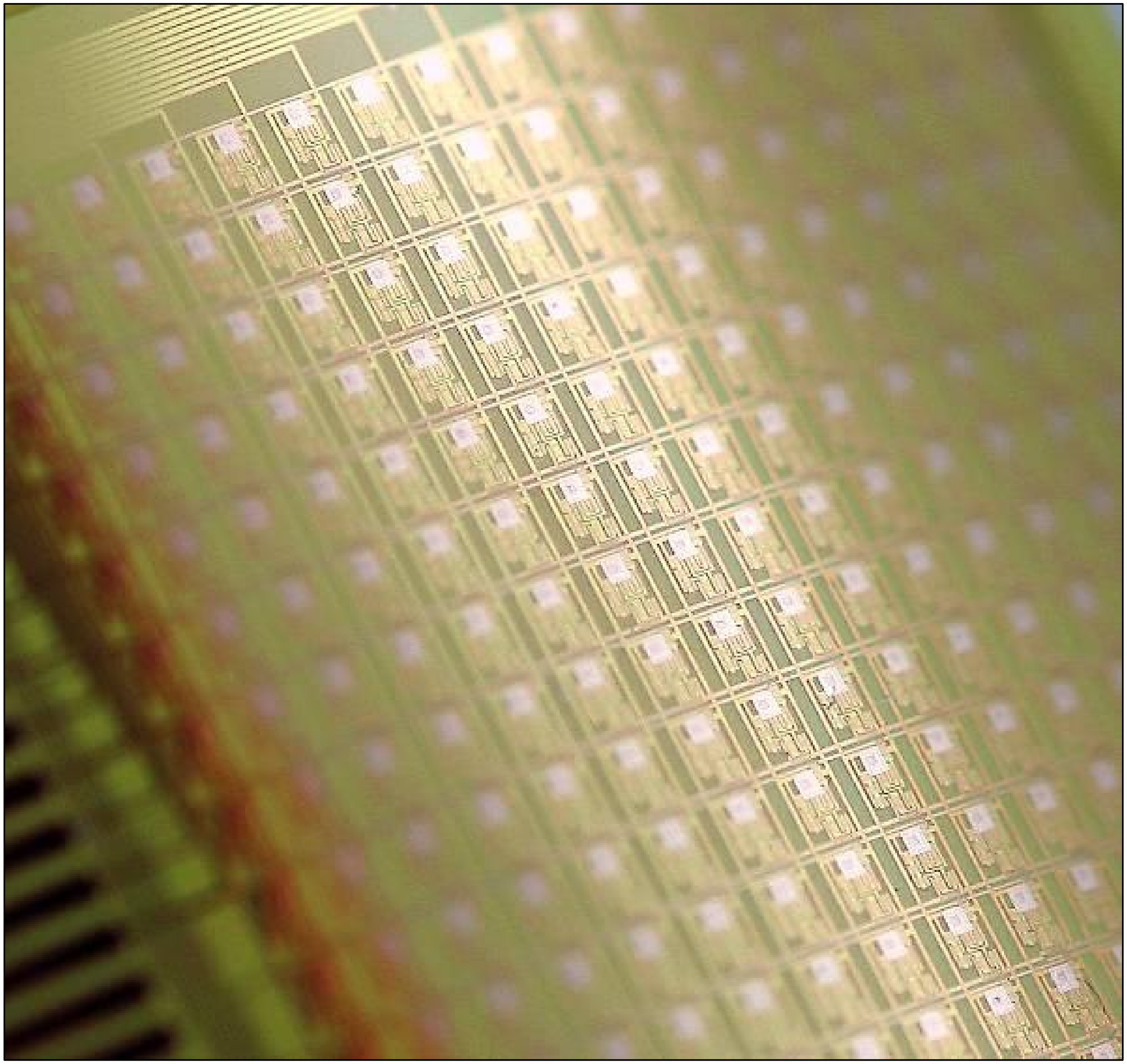
High Performance Electronics

1. Low Noise Amplifiers
2. Large Array Multiplexing
3. Sensor Arrays (Pressure, Temperature, etc.)
4. Photodiodes and Phototransistors

Optimized Materials and Mechanics

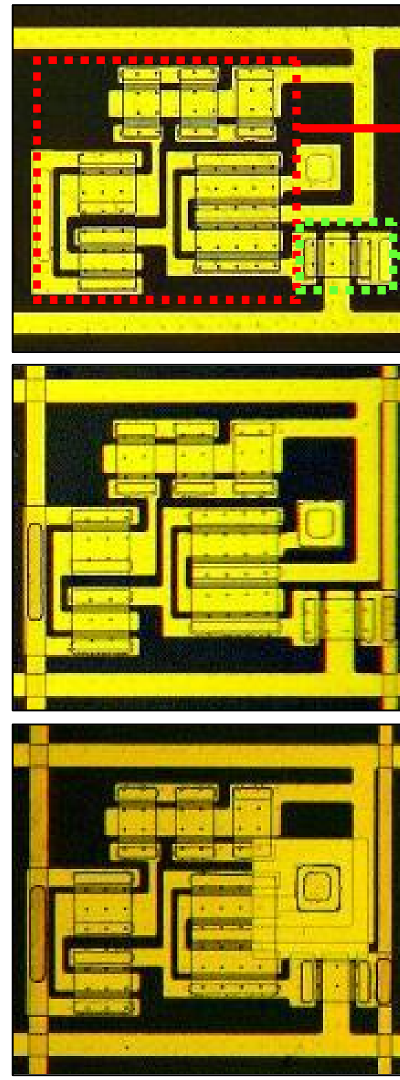
1. Modulus Matching to Body Tissue
2. Unfurl and Deploy within Cavities
3. Bend and Move with Catheter
4. Expand with Balloon Based Catheters

Arrays of Active Sensors



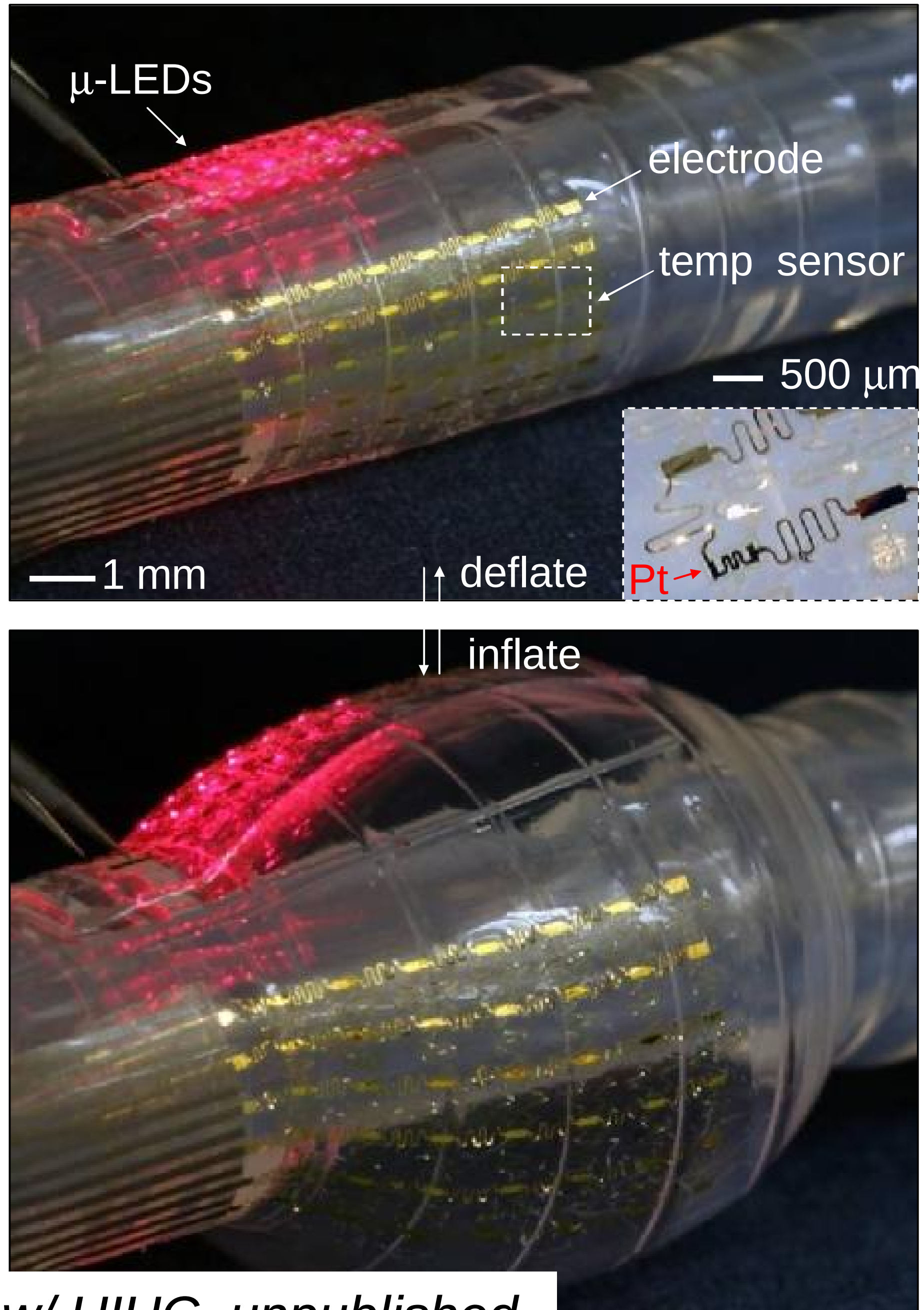
— 1 mm

- 288 (16´18) Sensor Array
- Multiplexing Capability
- 288´7=2016 transistors



— 200 µm

Multifunctional Optoelectronic Catheters



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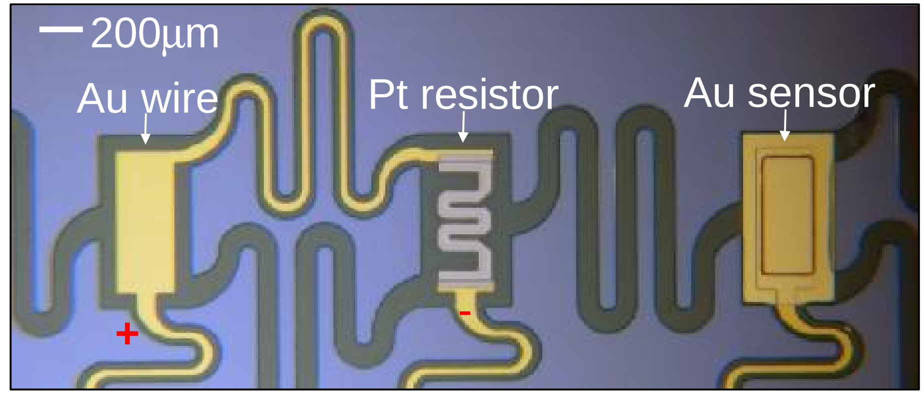
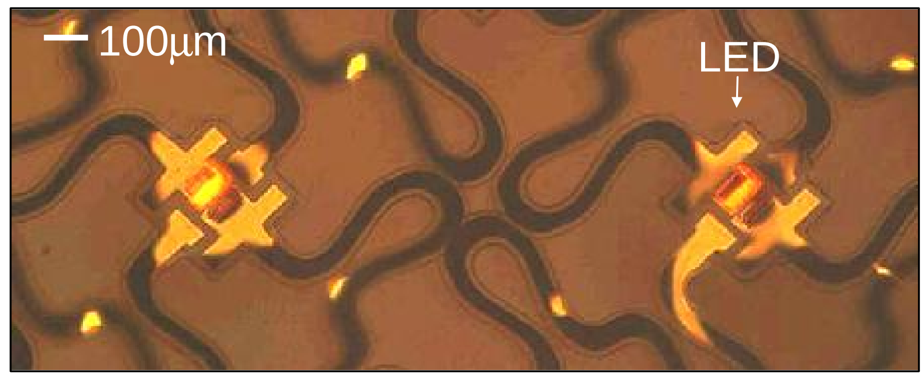
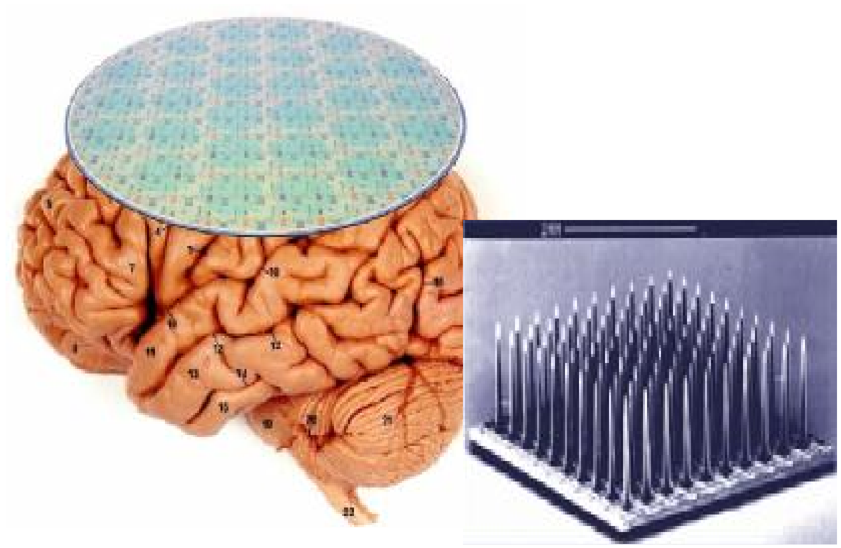


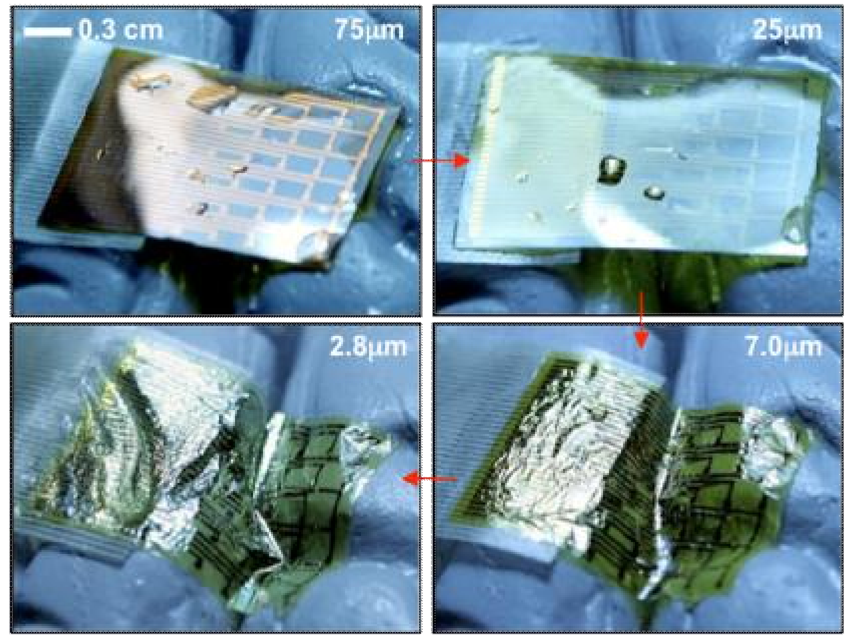


- Mapping / Stimulation / Ablation
- Temp. Sensing / Cooling
- Drug Activation

Biocompatible Electronics

Today → Tomorrow





Limitations:

Rigid
1 wire per contact
Complex I/O
"Passive" electronics
Tradeoff: resolution vs. coverage

→

Advantages:

Conforms to tissue, uniform contact
Tunable modulus
Active electronics
Multiplexing for minimal I/O
Local amplification of signal
High resolution and coverage

High Performance Brain Computer Interface

A Different Approach:

Conformal to Brain

3 - 25 µm thickness

High spatial resolution

Dense Active Electrodes

High temporal resolution

kHz sampling

Multiplexing & Amplification

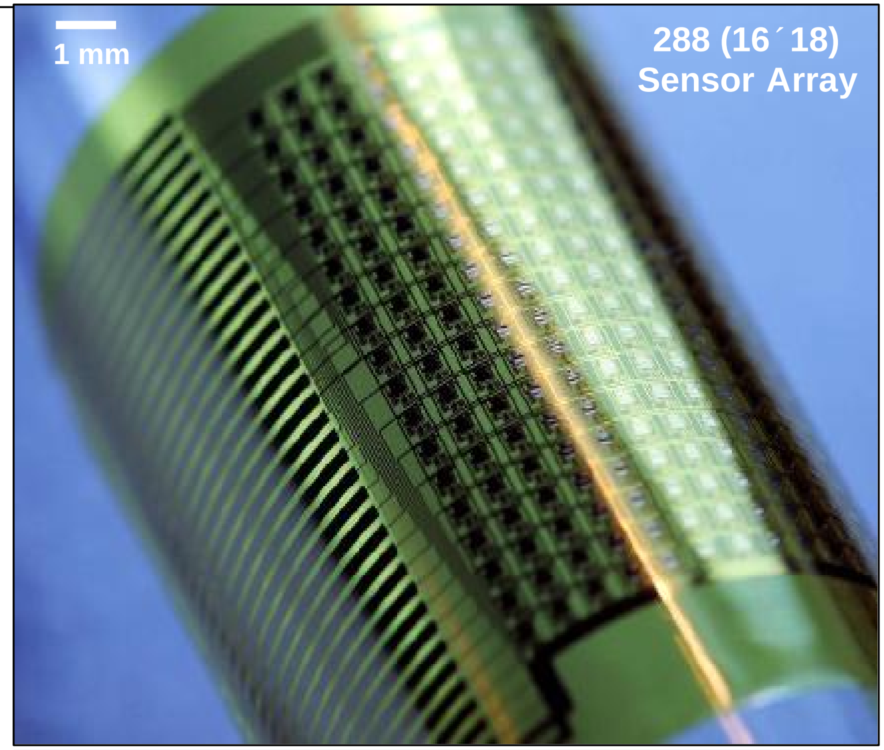
Few wires

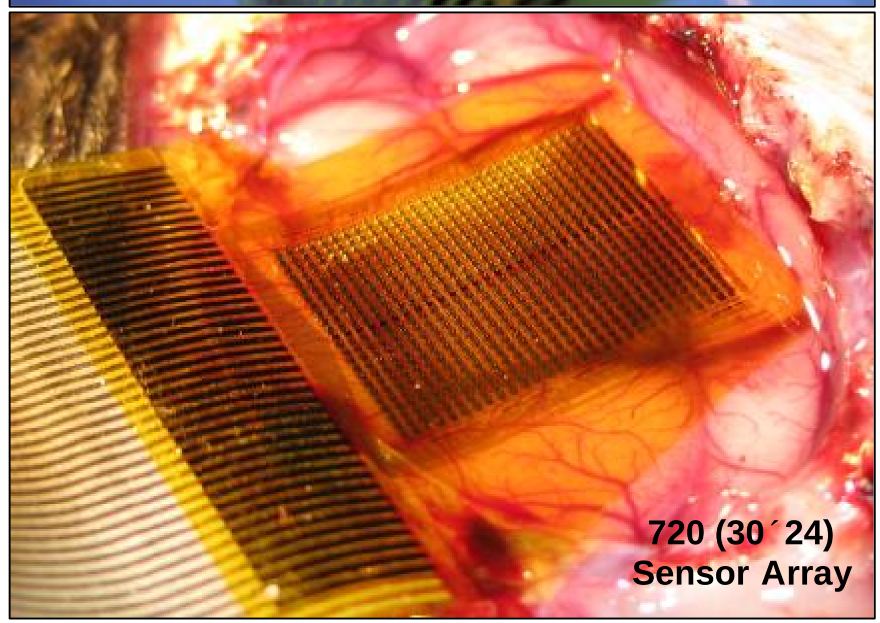
Amplifier beneath each electrode

Scalable

Advanced low power CMOS

With Tufts, UPenn, UIUC





Challenges, Needs and Opportunities

- Venture backed startups typically succeed when they develop products, not technologies or technology platforms.

- Most products that leverage advanced electronics are integrated systems that requires an array of components, capabilities and expertise outside the scope of one small company.

- Interface requirements are a major challenge!

- Federal funding cycles and topics (SBIR/STTR) are not well synced with commercial product development.

- Expedite Dual Use!