



Bioelectronics: Overview, Opportunities, and Challenges

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Bioelectronics

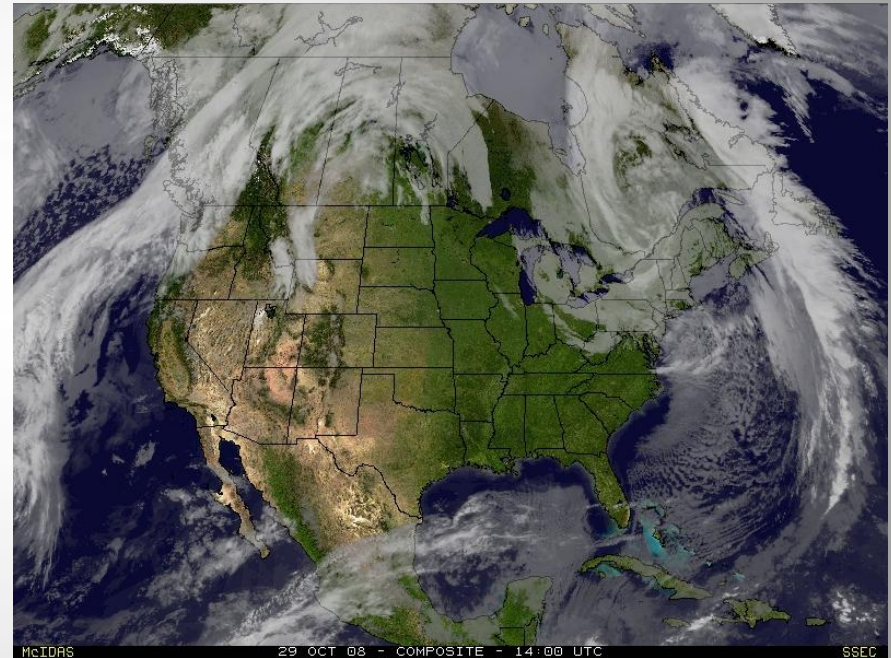




- **Most common definition**
 - Electrical engineering + bio*
- **Only 5 “bioelectronics” centers worldwide**
- **Lots of folks doing bioelectronics *in cognito***
 - Graduate programs
 - Research areas
 - Companies



Purpose of BERT





Working Definition



Bioelectronics encompasses a range of topics at the interface of biology and electronics. One aspect of bioelectronics is the application of electronics to problems in biology and medicine. This includes electronics for both detection, and characterization of biological materials, especially on the cellular and sub-cellular level. Another aspect of bioelectronics is the development of biological systems for electronic applications (e.g. processing novel electronic components from nerves, or other cellular components).

Bioelectronics also focuses on the interfacing of electronics with biological systems (e.g. brain-machine, cell-electrode, protein-electrode, etc). Applications in this area include assistive technologies for individuals with brain-related disease or injury, such as paralysis, and artificial retinas, and new technology for protein structure-function measurements.



Bioelectronics will focus on...

- **Characterization of cellular and sub-cellular materials**
- **Harnessing biology for electronics applications**
- **Biotic/abiotic interfaces**



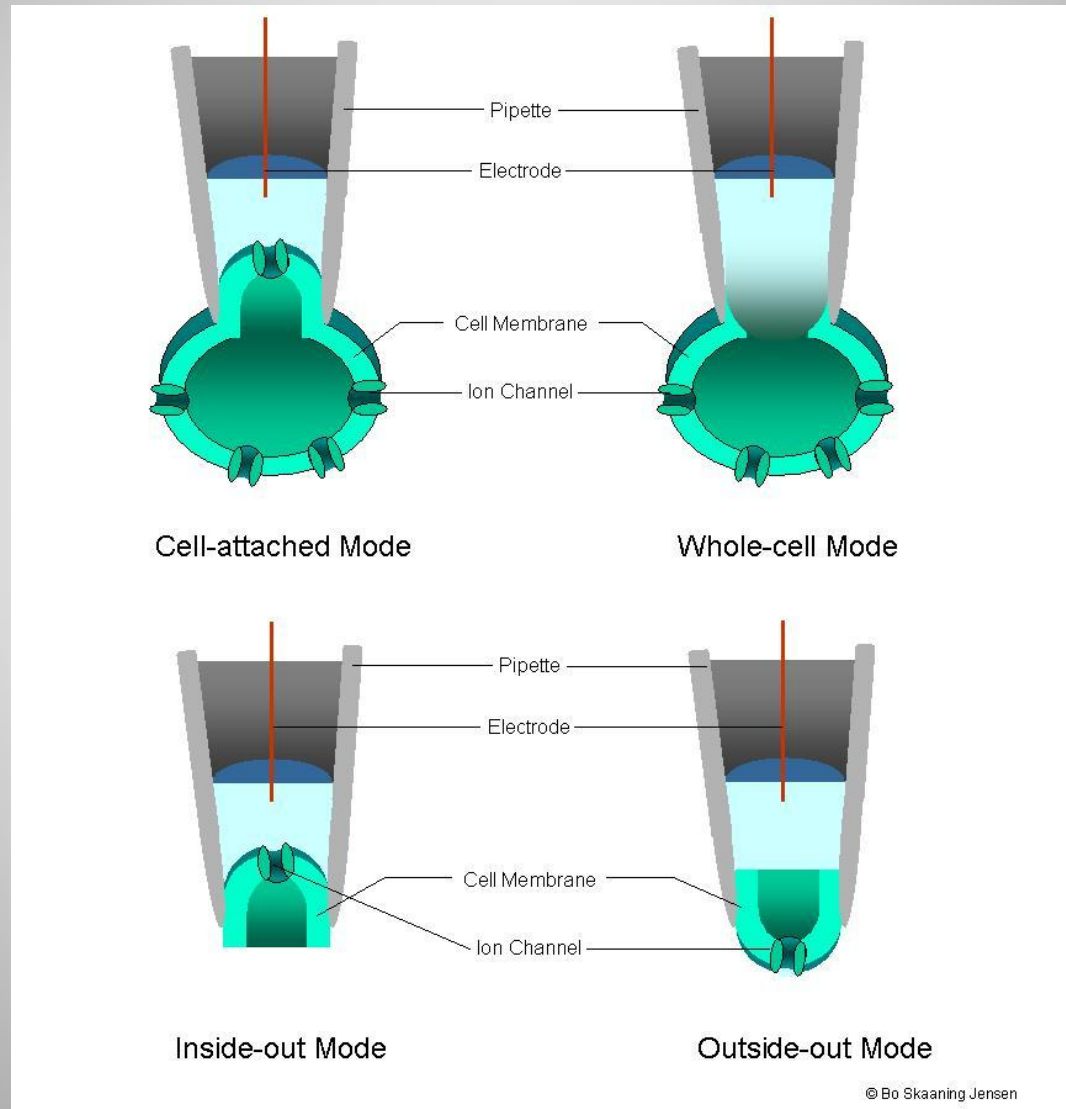
Overview

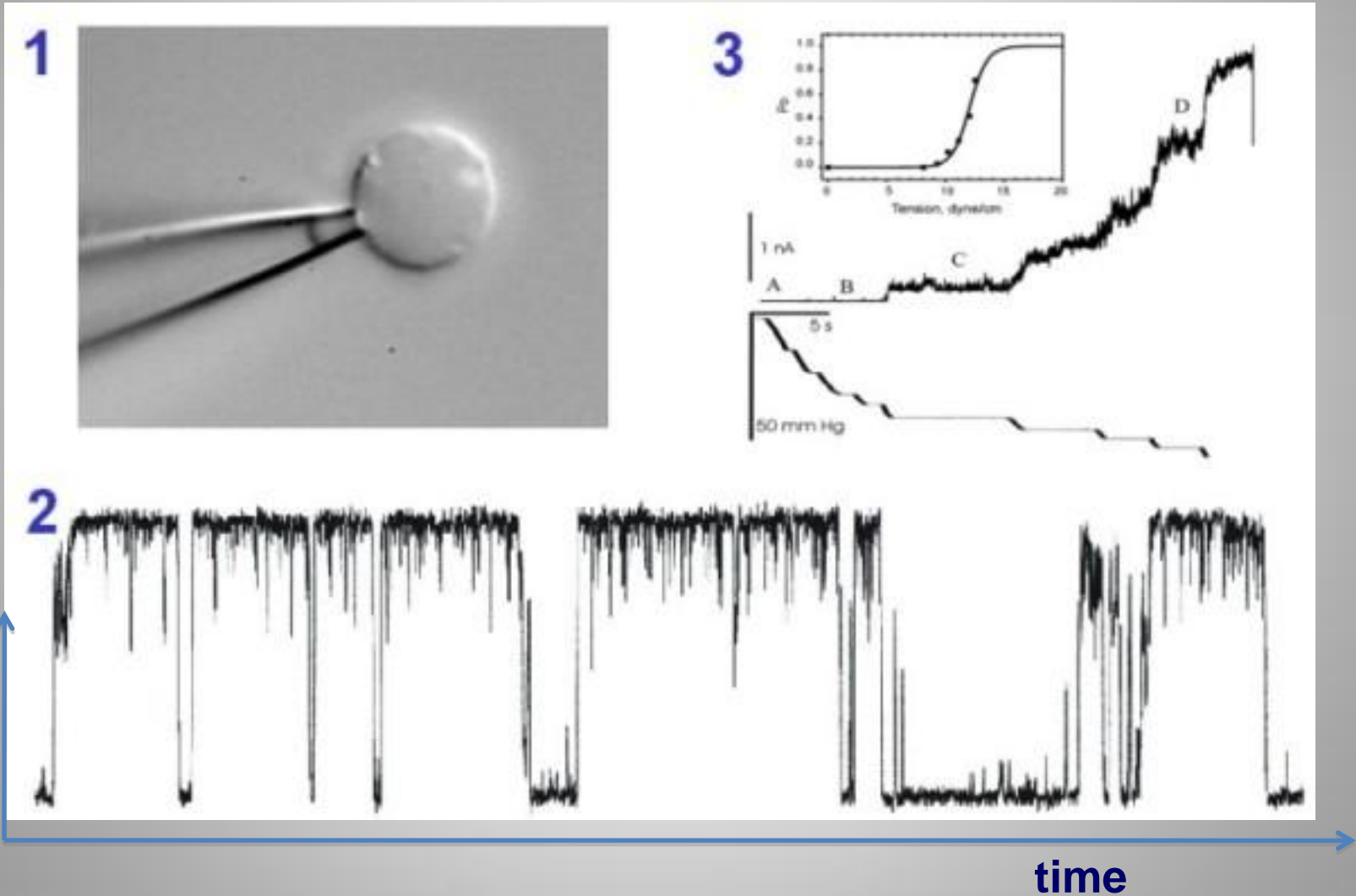


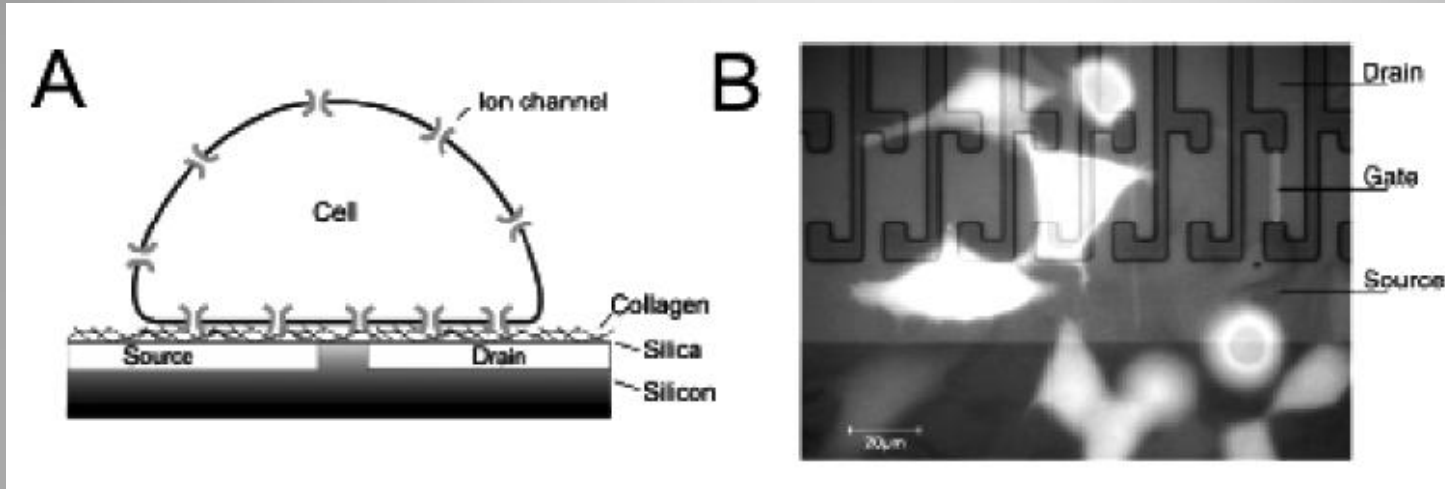
- **Characterization**
- **Building with biology**
- **Interfacing bioelectronics**



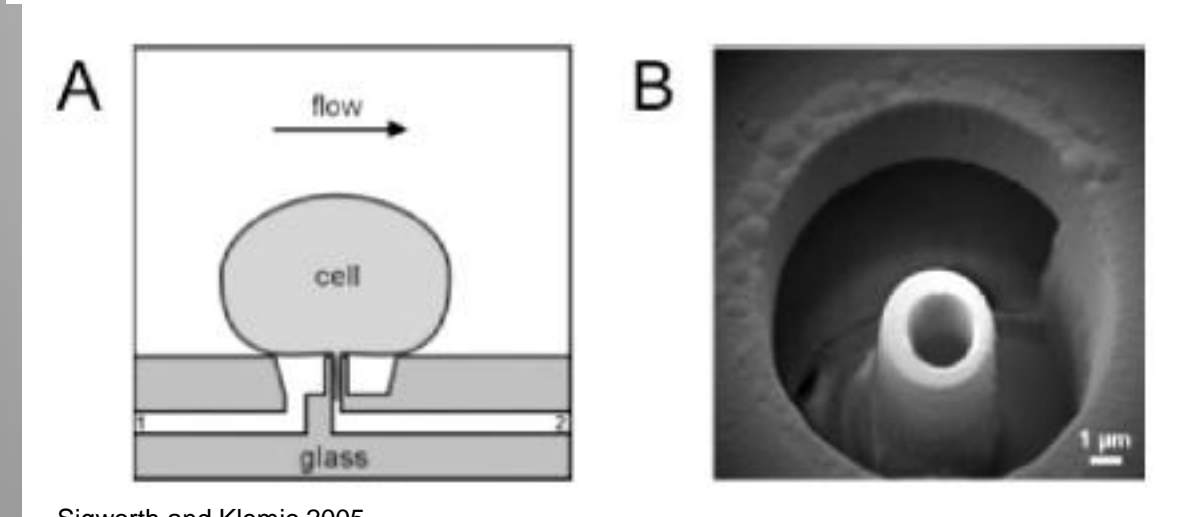
- **Usual suspects**
 - Patch clamps
 - What's going across the cell membrane?
 - Action potential
 - Electrical state of cell
- **Mechanical measurements**
 - How do mechanical forces influence cells?
 - What is the contractile force of single cells?
- **Thermal measurements**
 - Heat for quantifying molecular measurements
- **Others off the beaten path...**





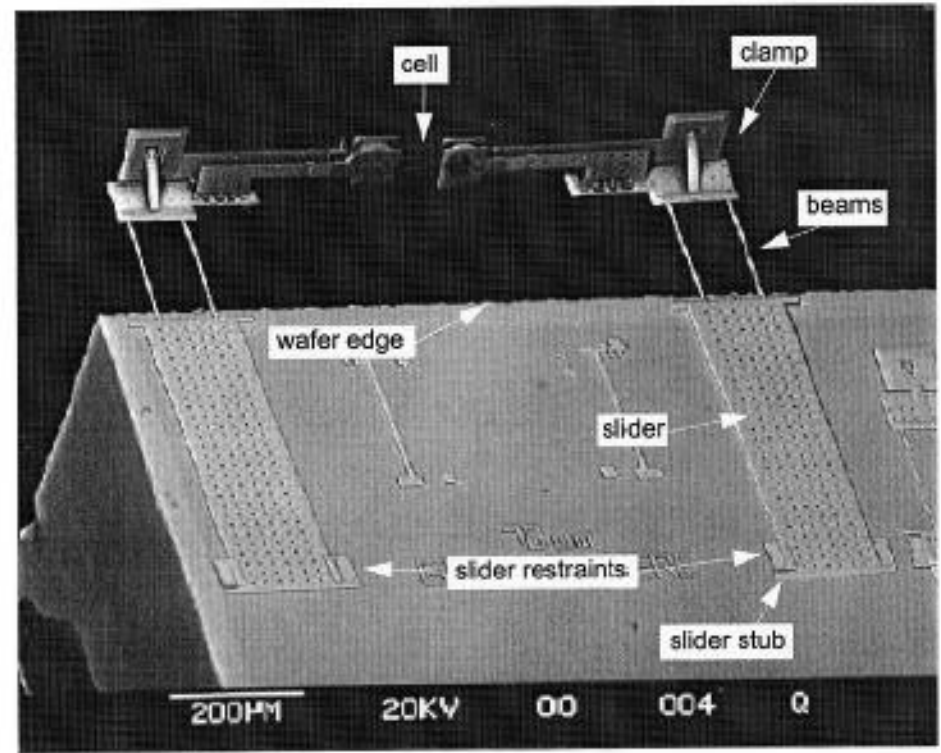
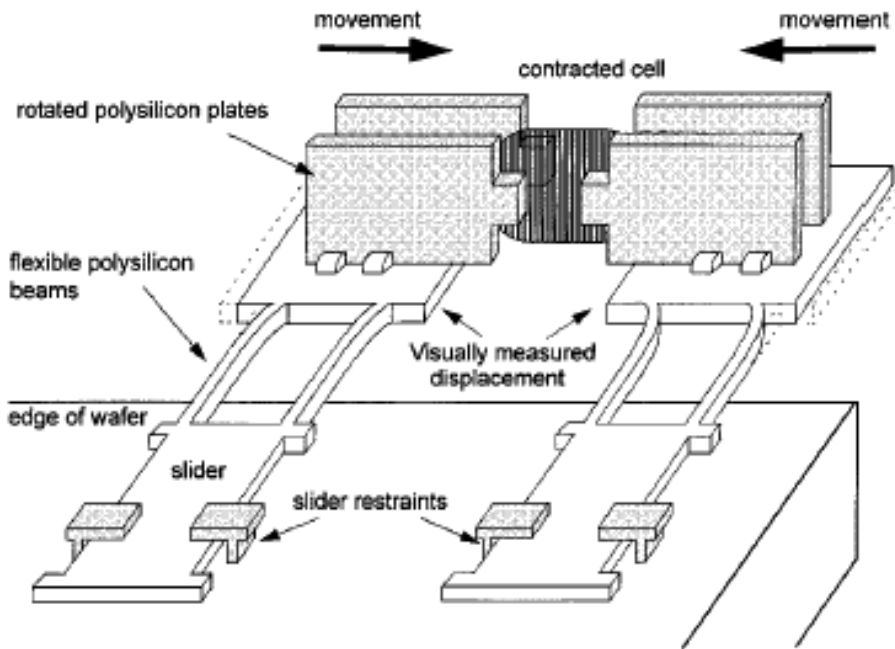


FET-based



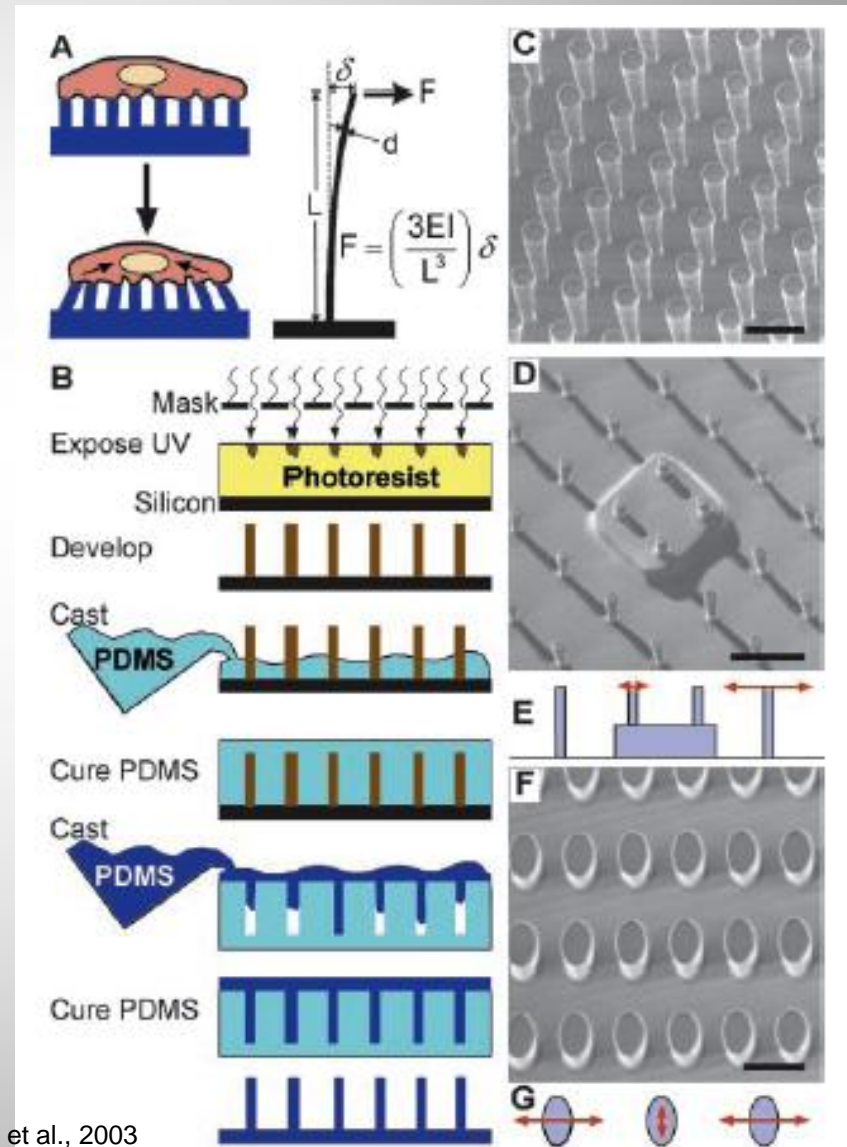
Needle-based

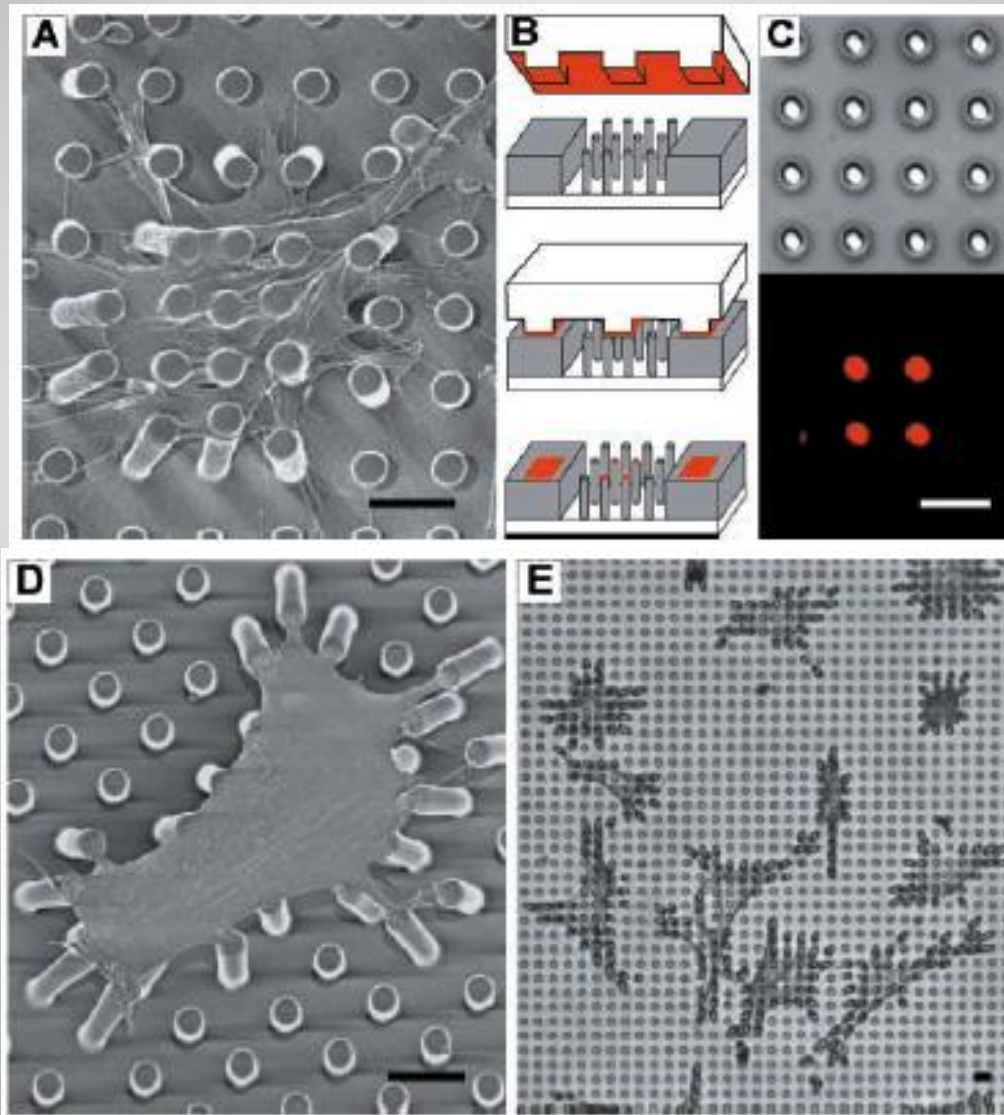
Sigworth and Klemic 2005

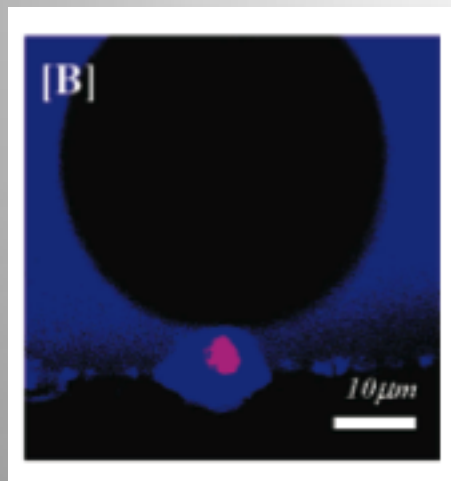
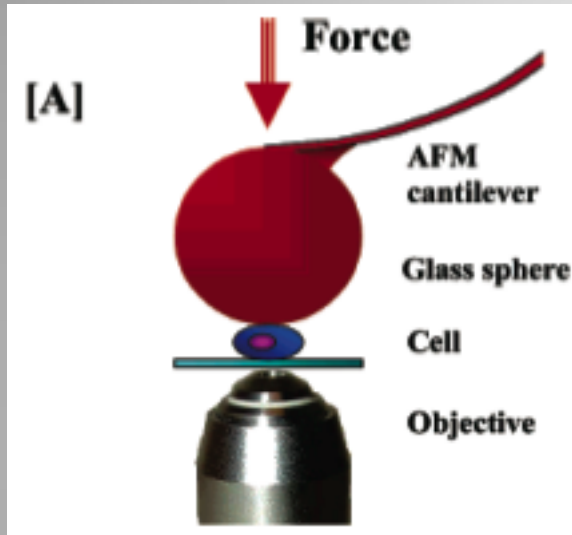


Lin et al., 2000

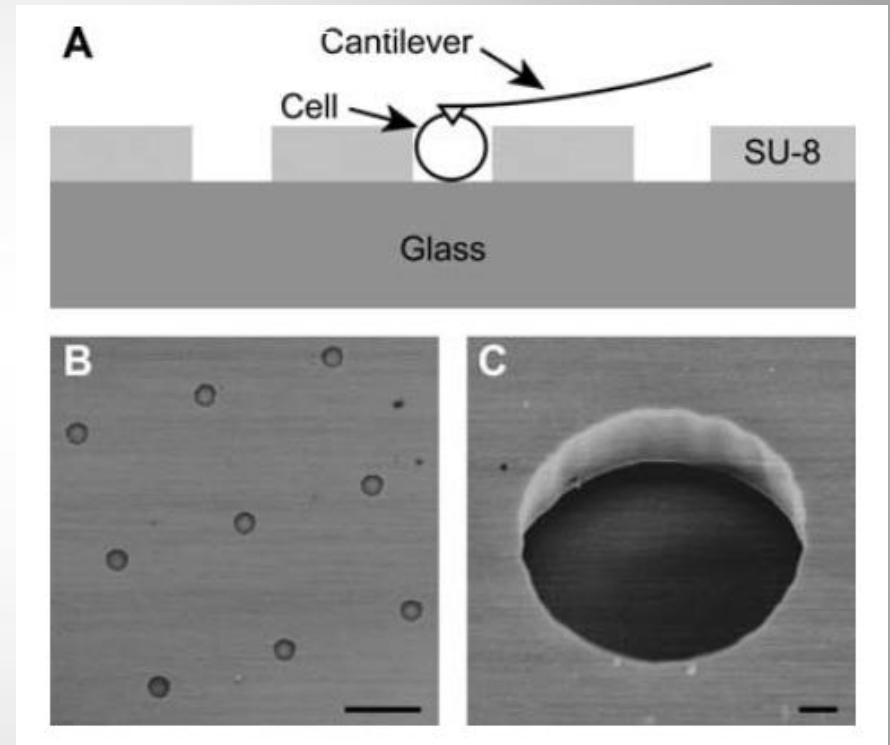
- Create vertical cantilevers
- Well-defined mathematically
- Place cells on top







Lulevich et al., 2006



Rosenbluth, et al., 2006

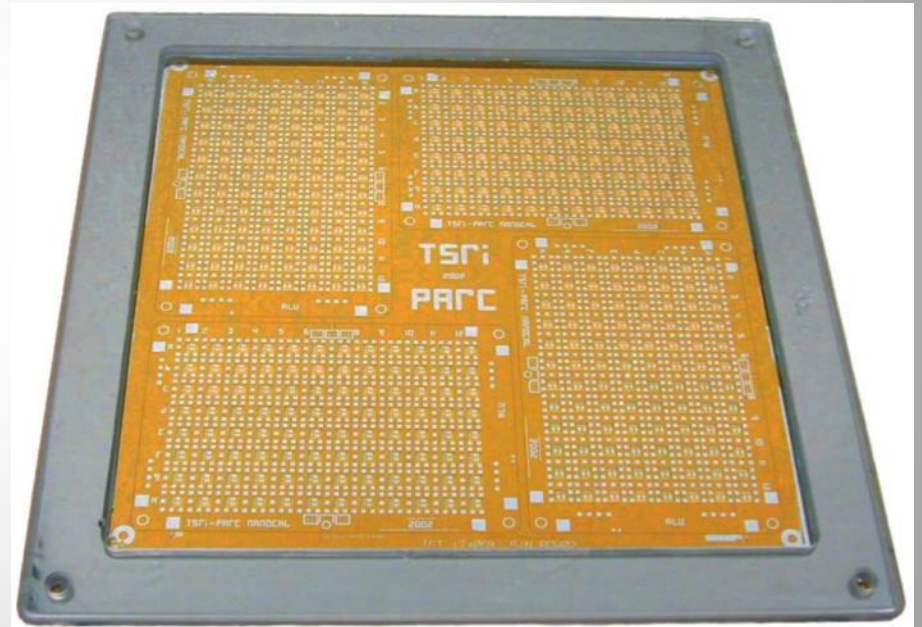
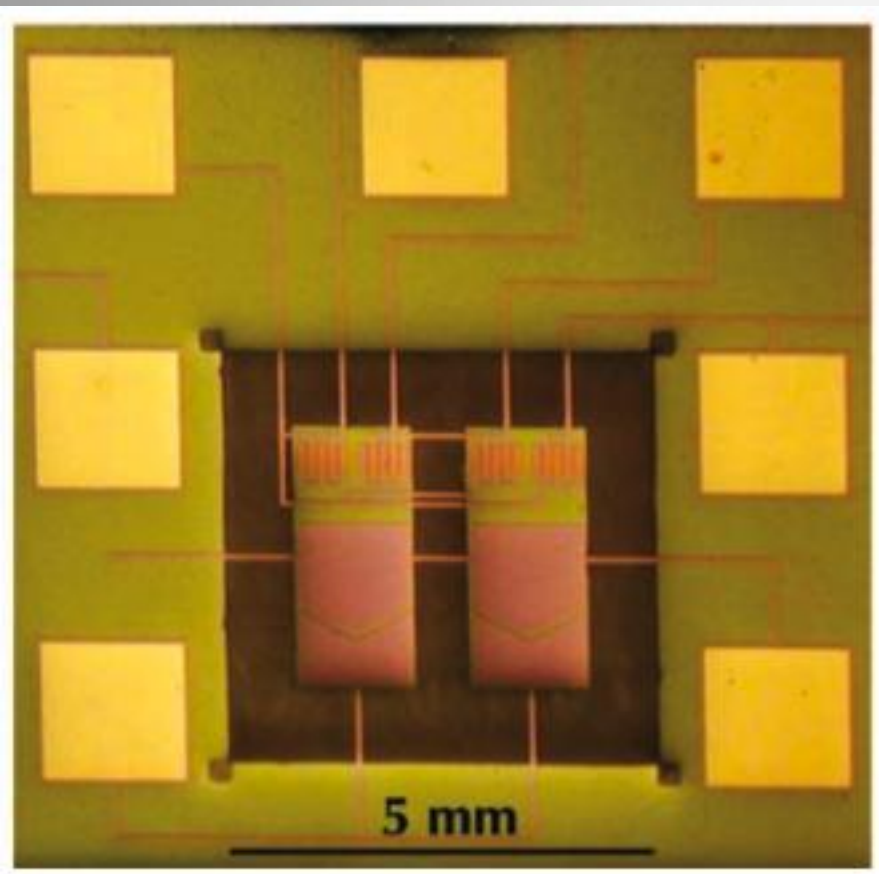
Other ways?



Enthalpy Array

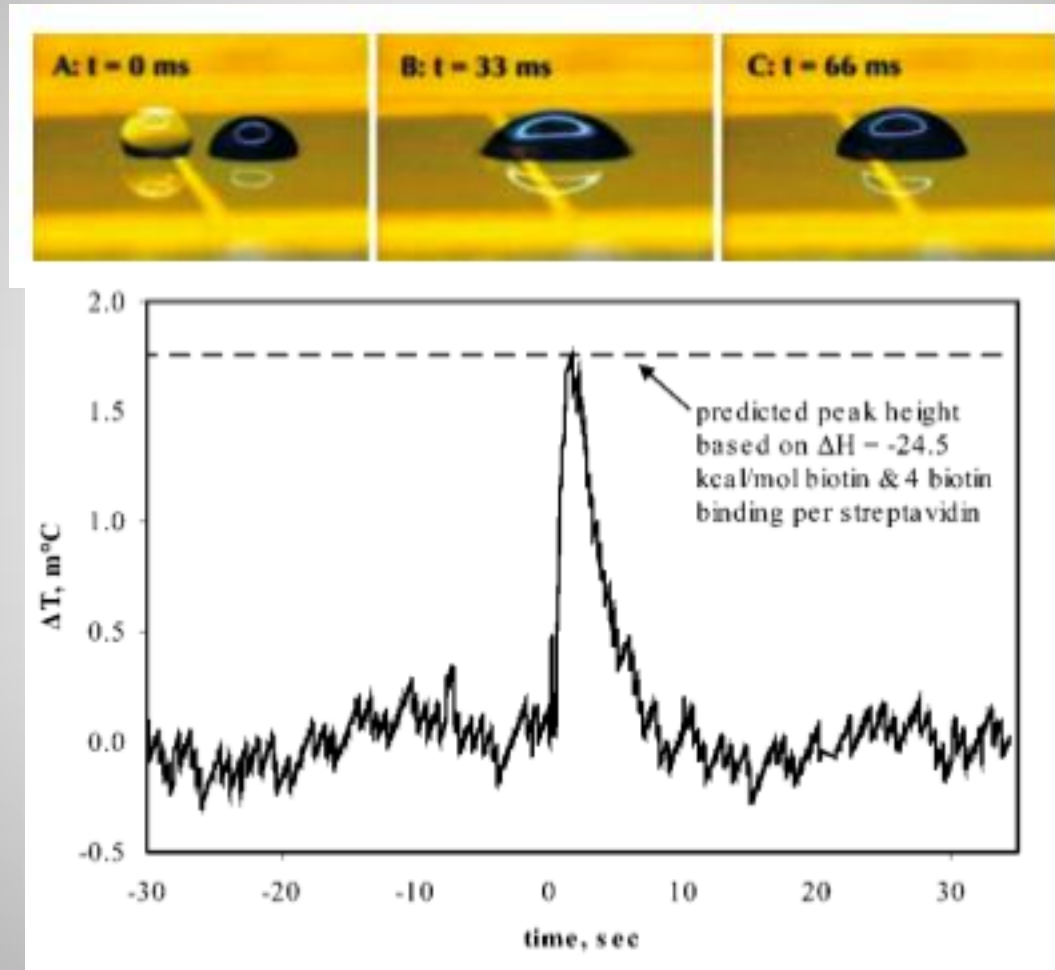


Enthalpy arrays for quantifying biomolecular interactions



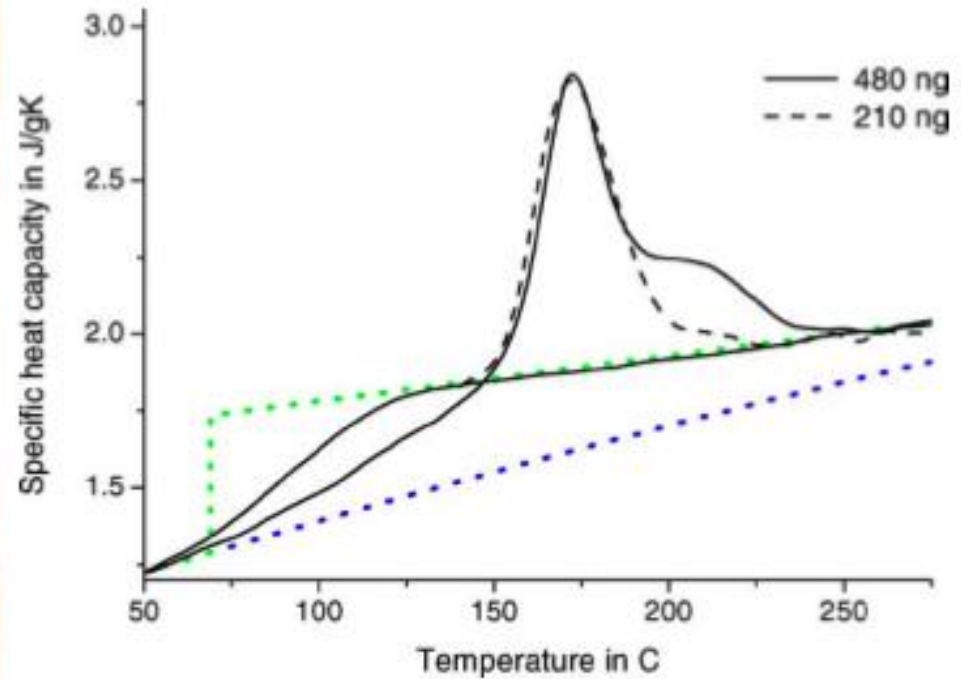
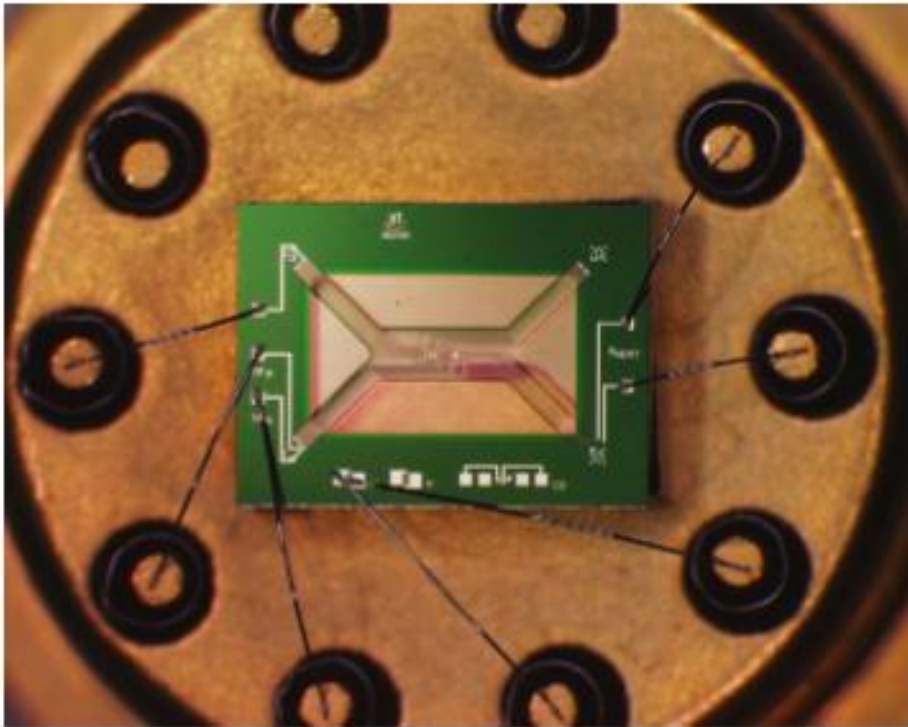
Torres, et al., 2004

Bioelectronics Roundtable * November 4, 2008



Torres, et al., 2004

Scanning calorimetry for sensing molecular configuration



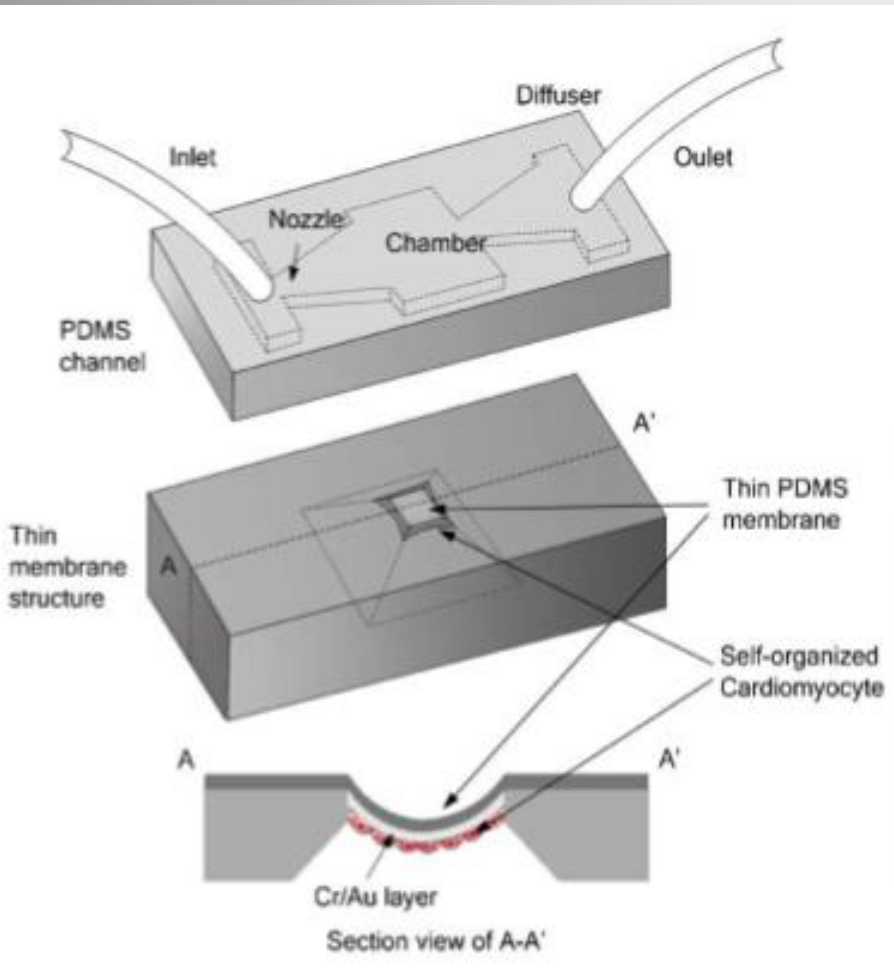
van Herwaarden, et al., 2005



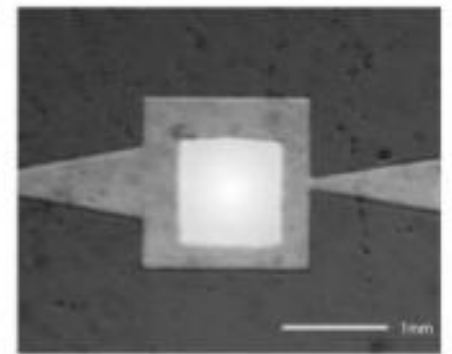
- **Patch clamp**
 - Obvious choice
 - Very much an art
- **Contractile forces**
 - Needed to elucidate mechanotransduction mechanisms
- **Cell squeezing**
 - Cell stiffness = unique identifiable marker
 - Cancer
- **Thermal**
 - Growing area
 - Integration with existing processes
 - Useful properties can be measured (better?)



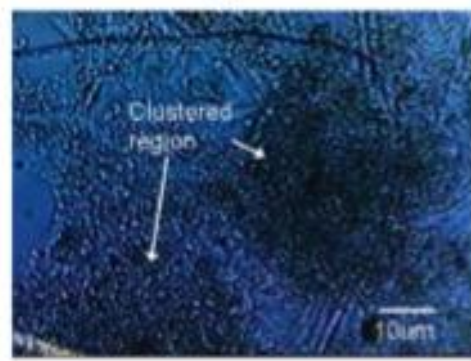
- **Cells as actuators**
 - Optimized for the microscale
- **Assembling with viruses**
 - Precise fabrication
- **Molecular trains**
 - Actin-myosin to transport nanoscale objects
- **Whole-cell biosensors**
 - Cell as “canary in a mine”



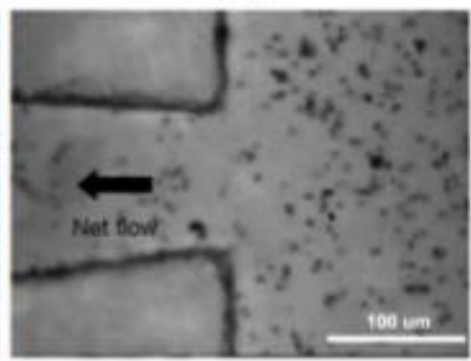
(a)



(b)

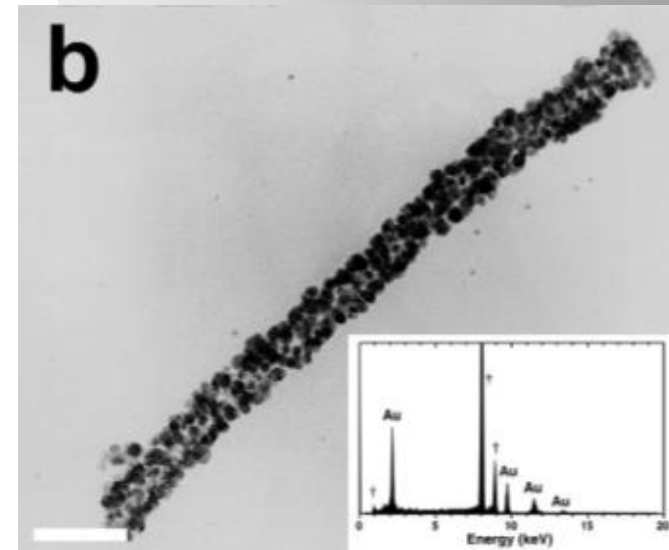
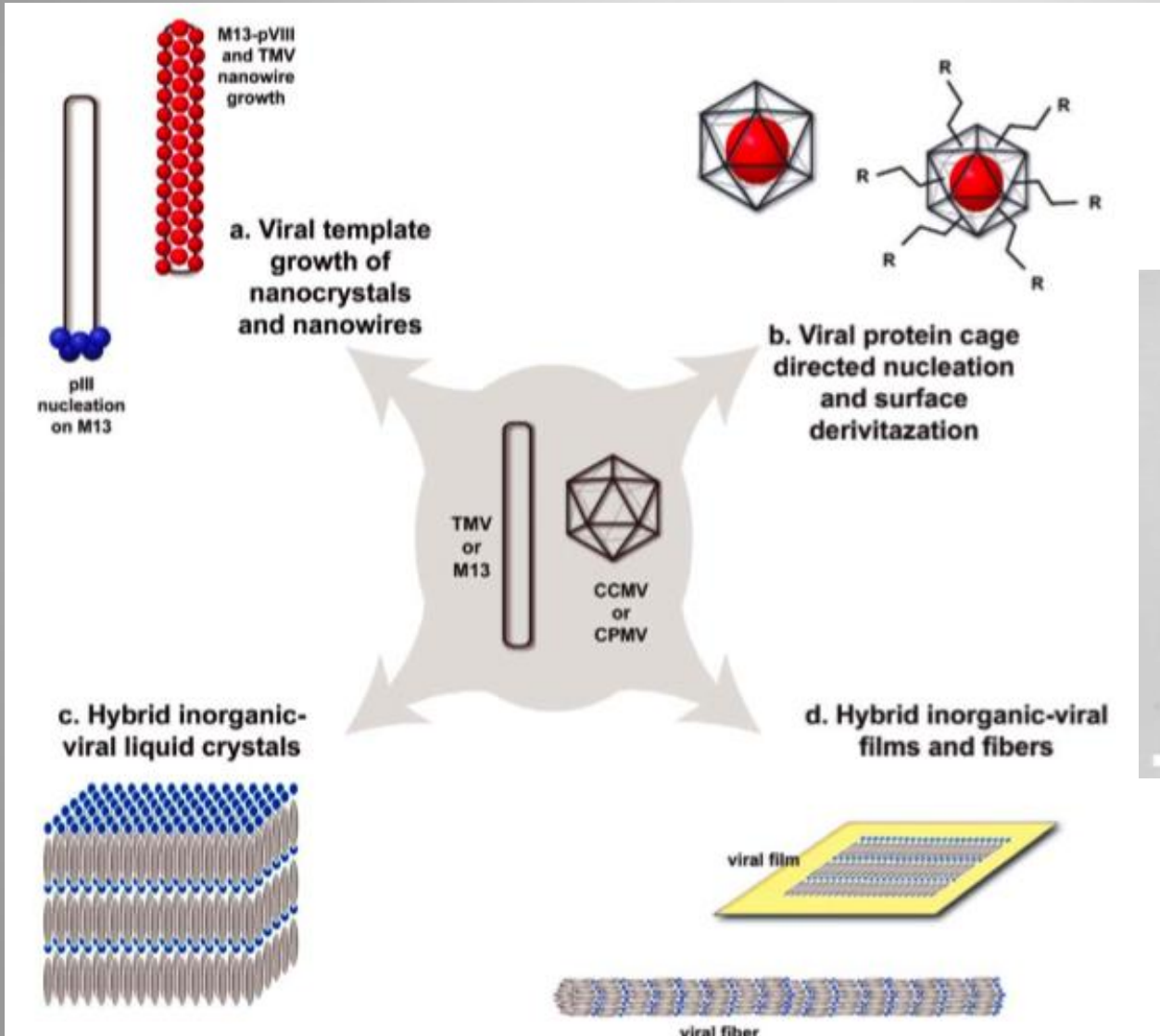


(c)

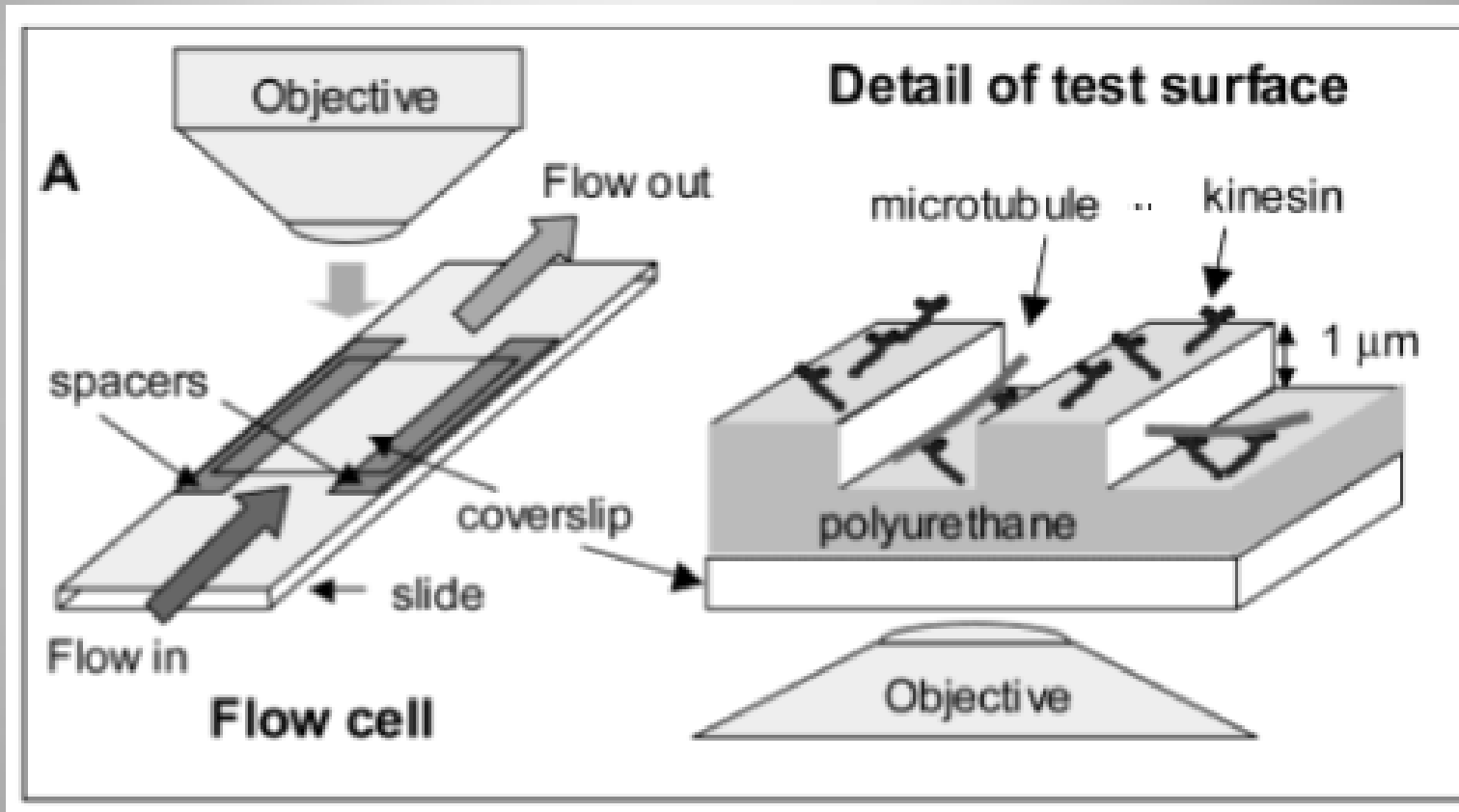


(d)

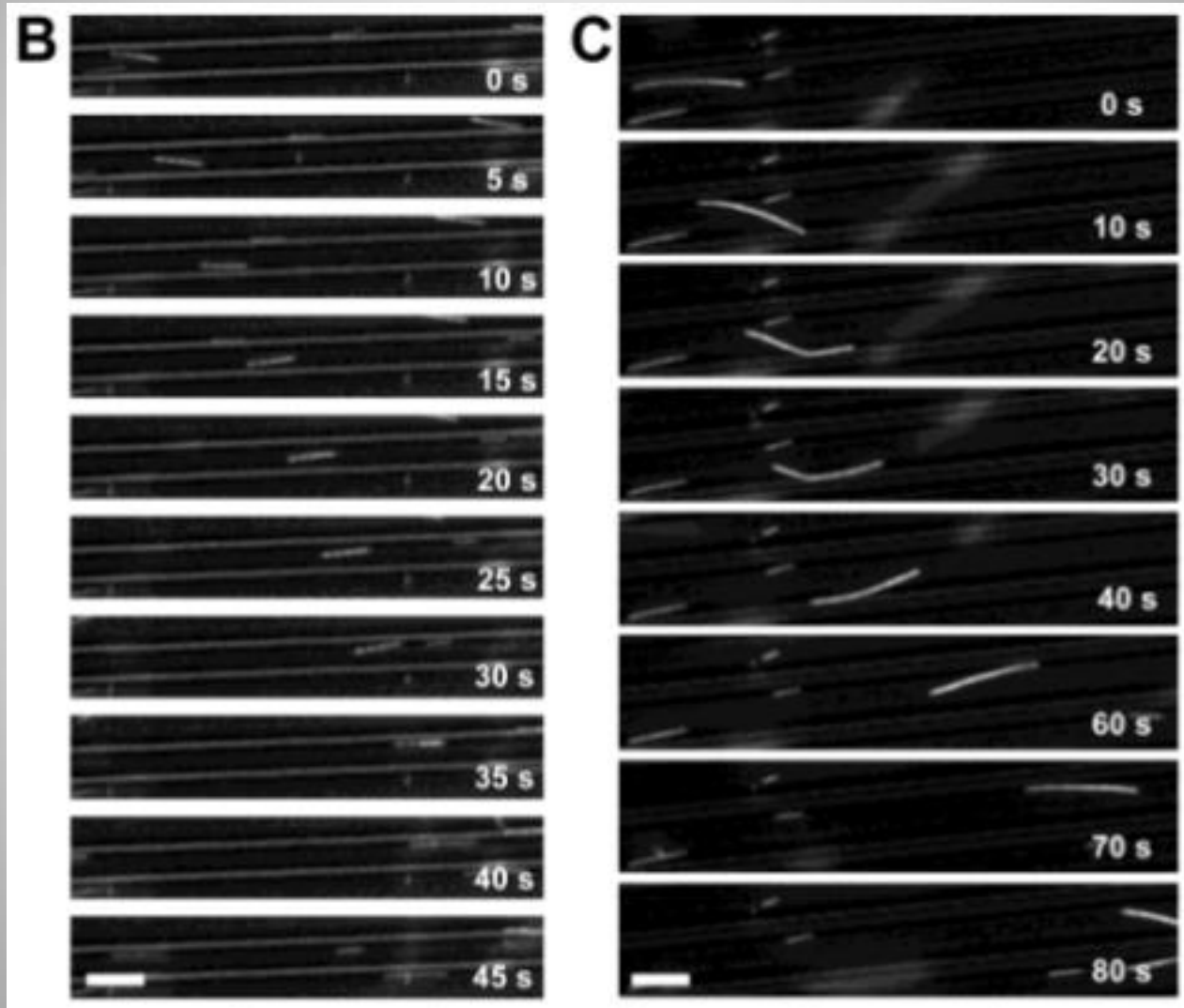
Park et al., 2007



Flynn et al., 2003

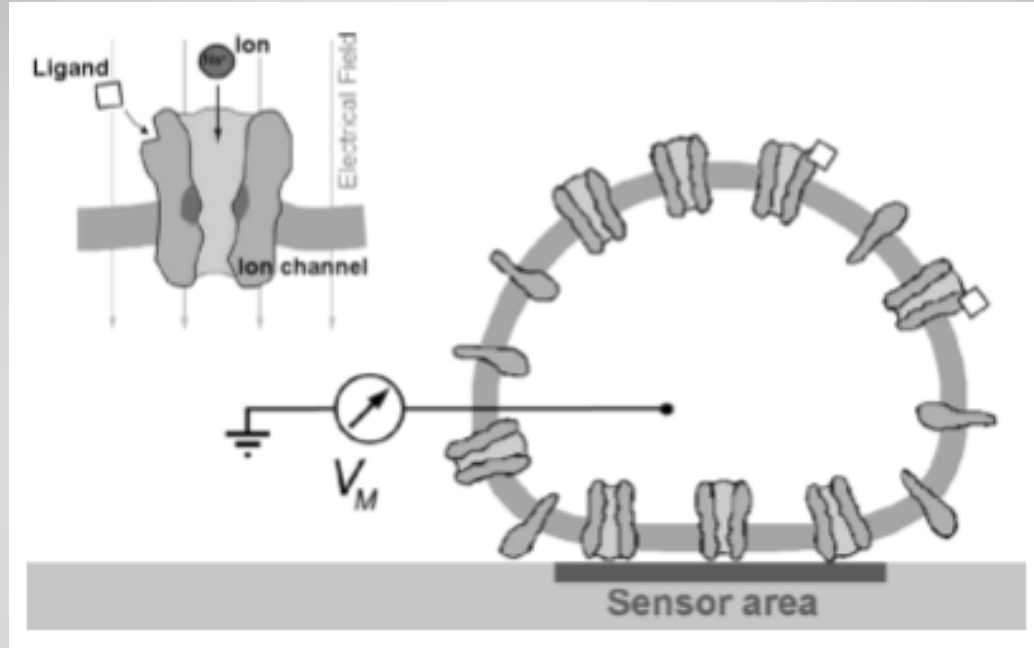


Clemmens et al., 2003

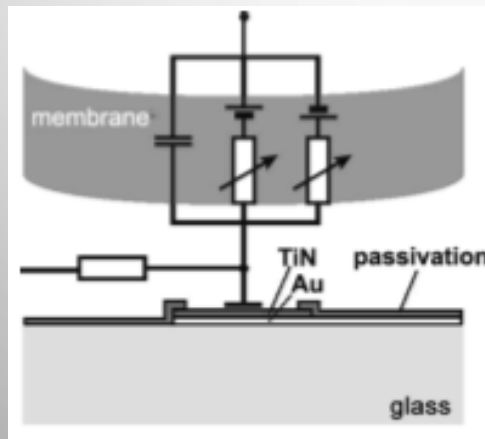


Clemmens et al., 2003

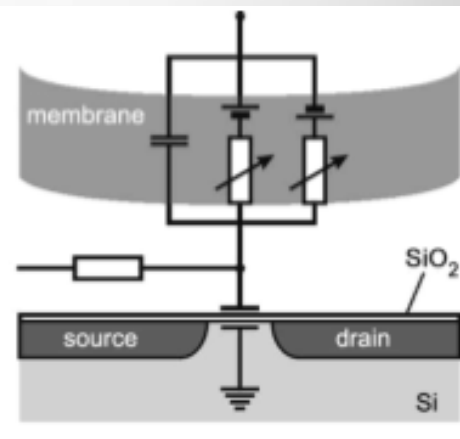
Scale bar = 4 μ m

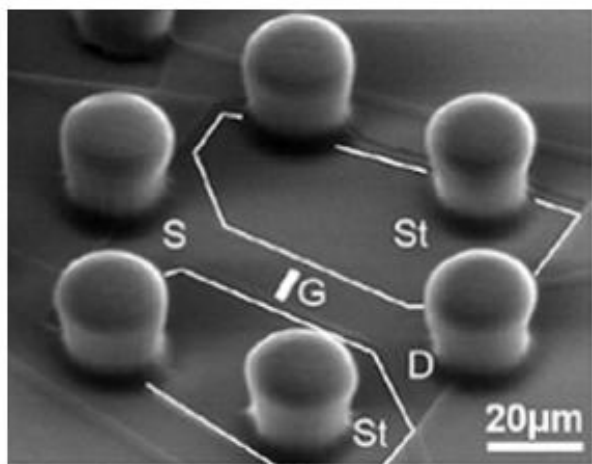


Metal electrode

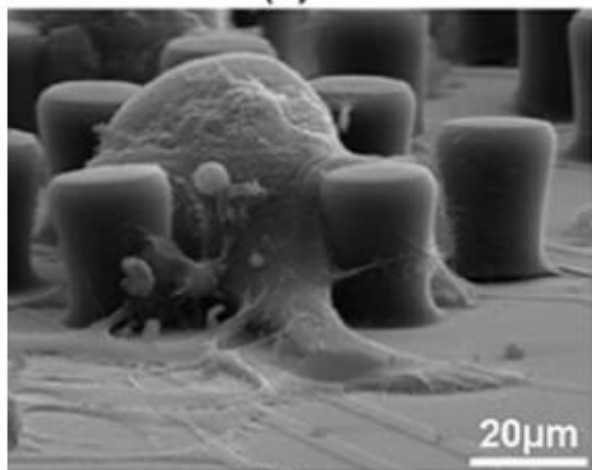


FET

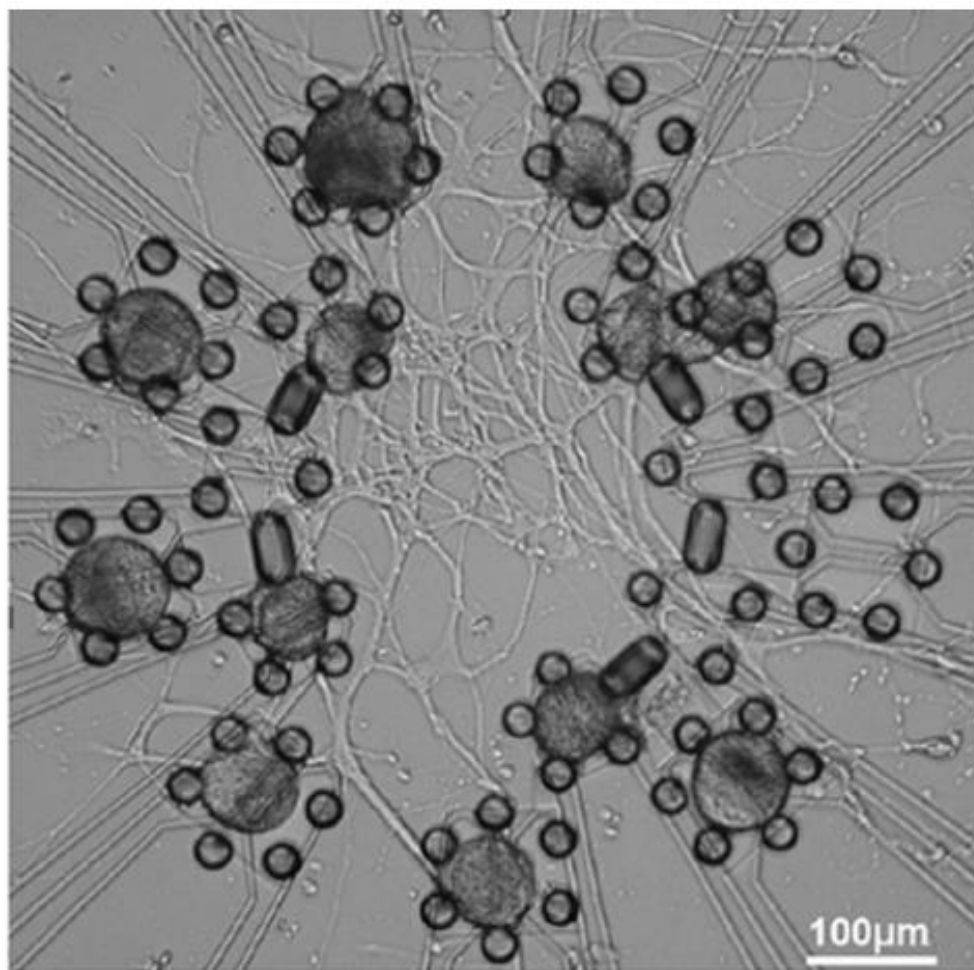




(a)



(b)



(c)

Jenkner et al., 2004



Summary



- Still in infancy, but encouraging results
- Nature values function over precision
 - Effect on final product?
- Works at room temperature
 - Flexible process parameters
- How to integrate with existing technology?

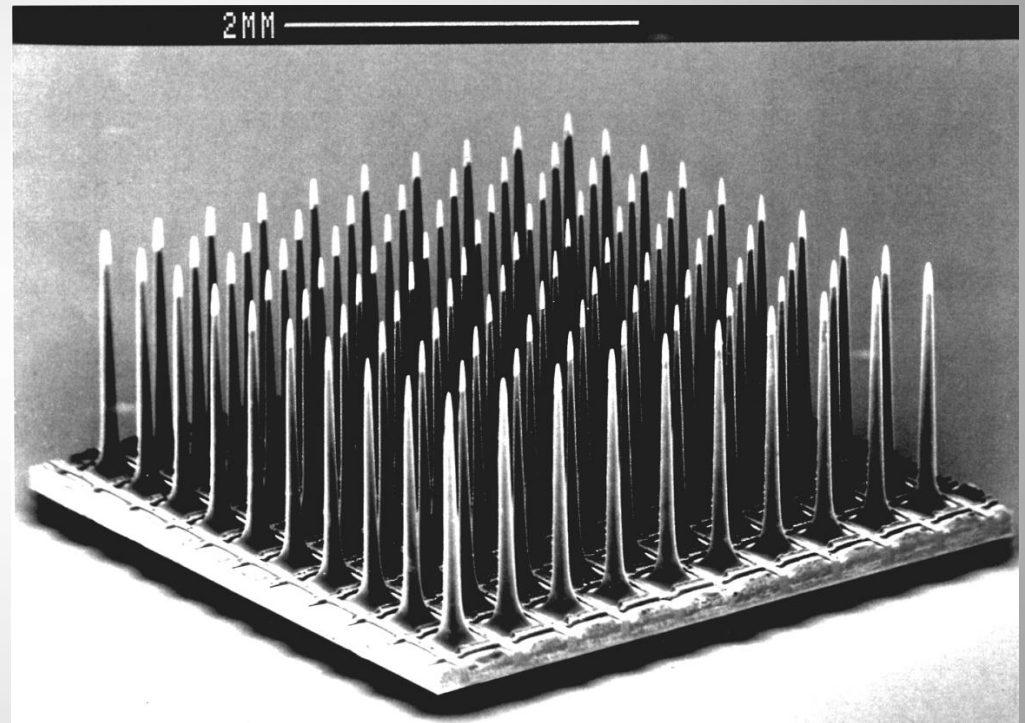


Biotic/abiotic Interfaces



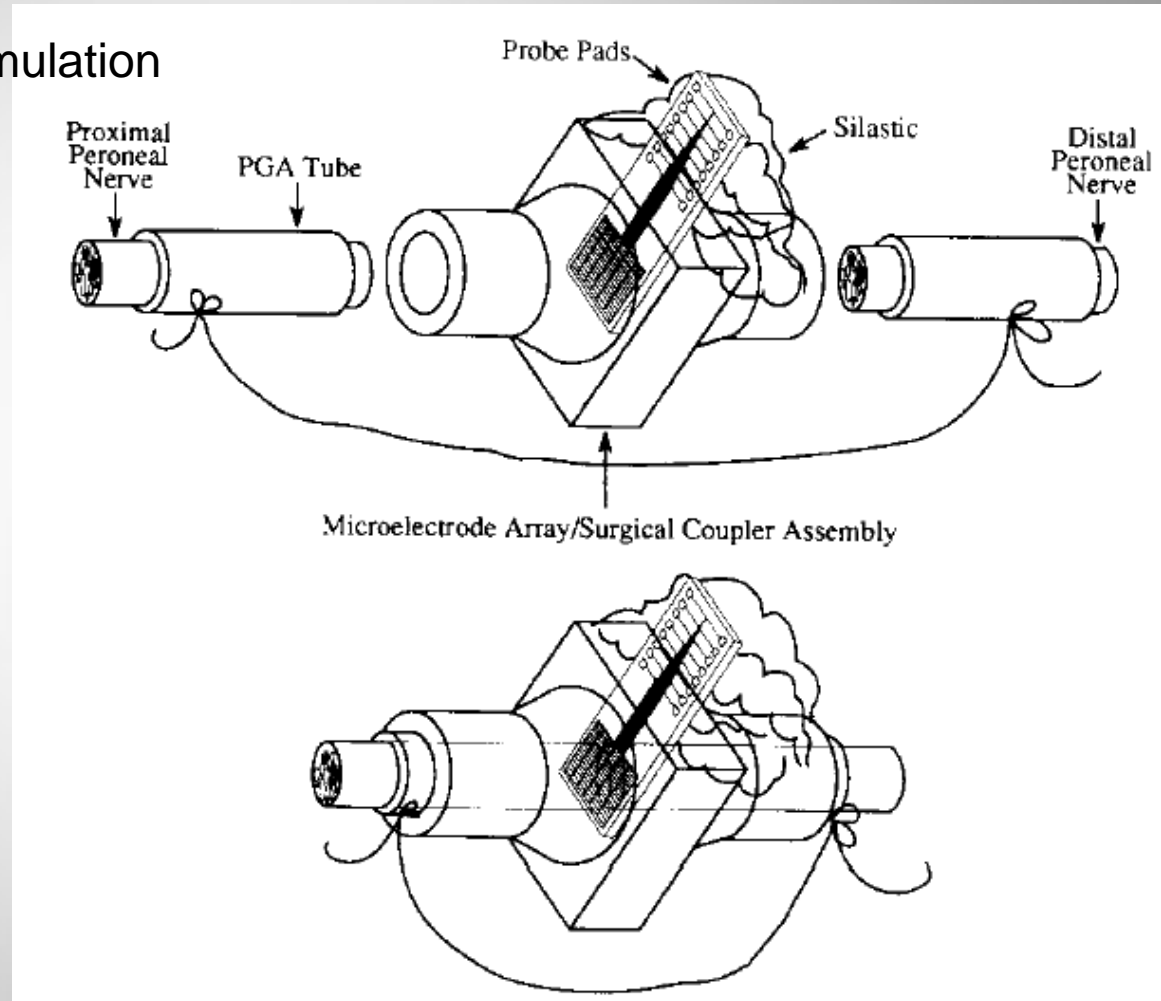
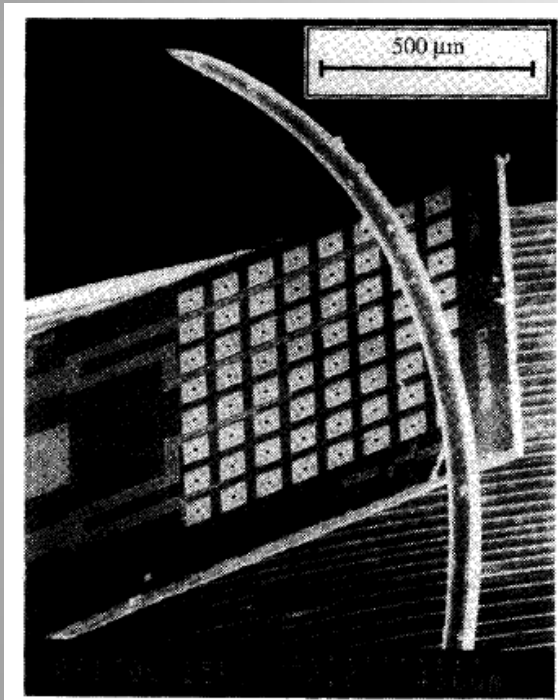
- Retinal Implant
 - Restoring sight. More info later.
- Neural Implants
 - Brain stimulation (e.g., Parkinsons)
 - Peripheral nervous system (restore limb function)
- Ear Prosthetics
 - Cochlear implants
- Drug Delivery
 - Intelligent drug delivery

- Array of electrodes
- Implanted
- Listen and/or stimulate

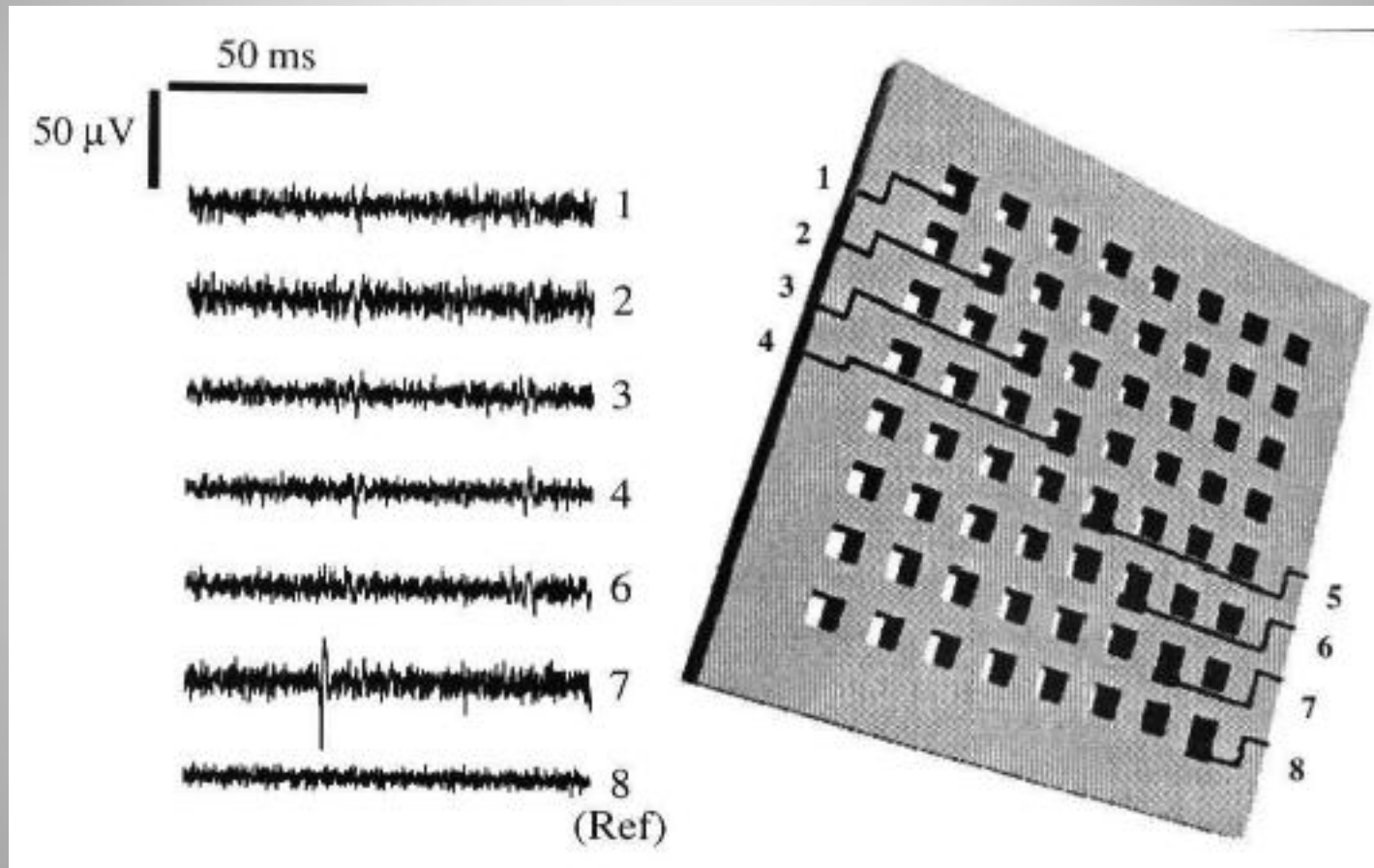


University of Utah electrode array

Peripheral recording and stimulation

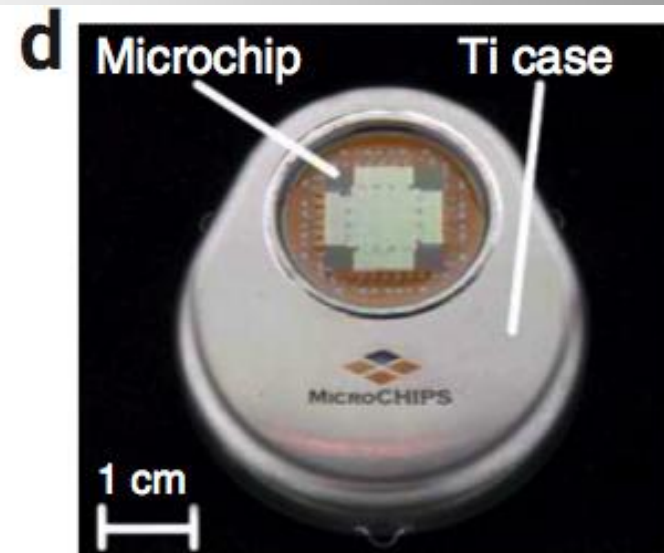
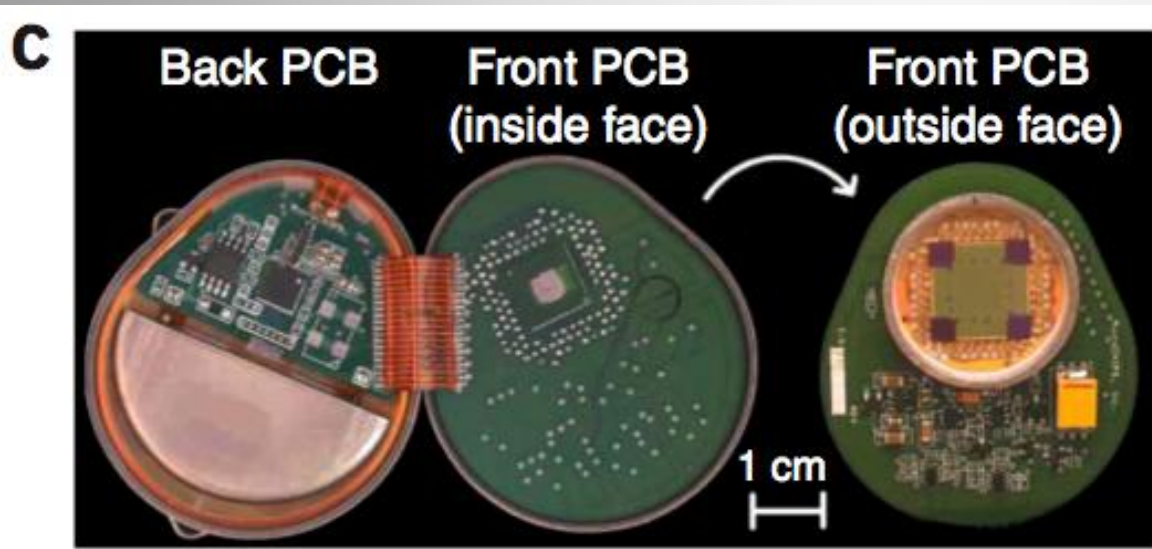


Kovacs et al., 1992

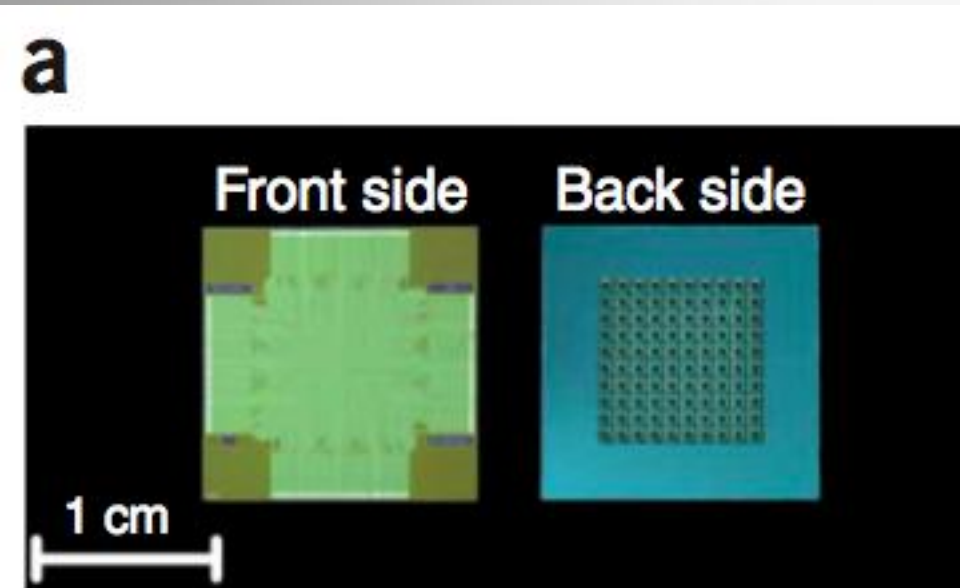


Kovacs et al., 1992

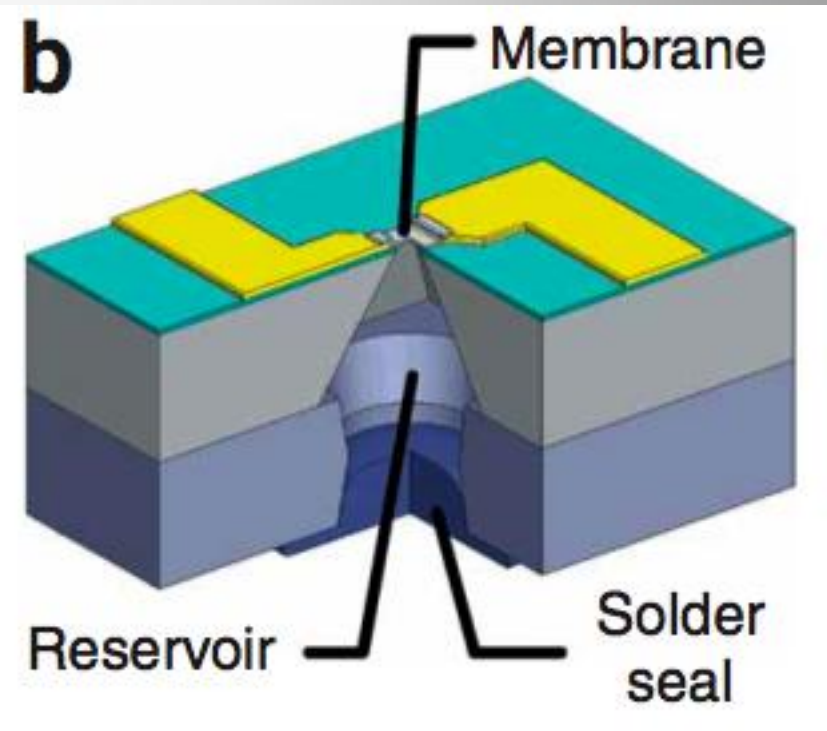
MicroCHIPS



Prescott et al., 2006



Prescott et al., 2006





Summary



- It's all about the surfaces
 - Biofouling
 - Sensor life
- Neural
 - Repeatability
 - Movement
- Drug Delivery
 - Need advantage for implantation
 - Prolonged sensor life