

**Microelectrode arrays employing collagen
for
improved neural recording**

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Outline

- Motivation for biological / electronic interfaces
- Biocompatible electrode arrays
- Properties of collagen
- Goals for using collagen for interfacing
- Experiments with collagen matrices
 - Epithelial cells on collagen
 - Explanted neurons on collagen
- Electrode fabrication and assembly
- Experiments with electrodes
- Summary and outlook

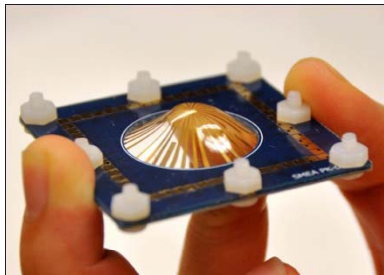
Motivation for biological / electronic interfaces

- *In vitro*
 - Model for traumatic injuries
 - Traumatic brain injury (TBI)
 - Spinal cord injury (SCI)
 - Tissue engineering
 - Mechanical strain and electrical stimulation
- *In vivo*
 - Mechanically active biological tissues
 - E.g., muscle, bladder, peripheral nerves, cardiac tissue
 - Very soft tissue
 - Brain

Biocompatible electrode arrays

In vitro:

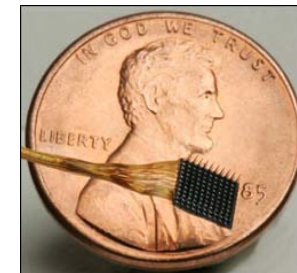
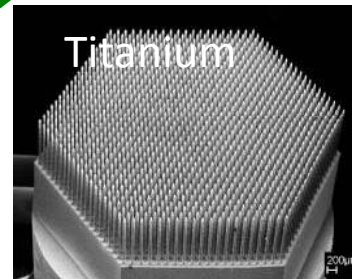
Interfacing with a tissue or dissociated cells cultures



MEA in culture chamber
(Multi Channel Systems)

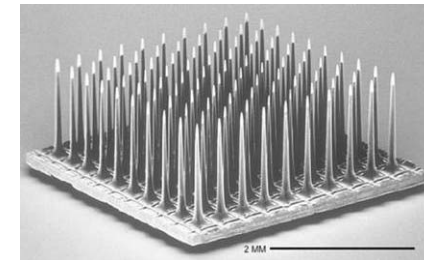
In vivo:

Interfacing with neurons in the body of an animal or a human

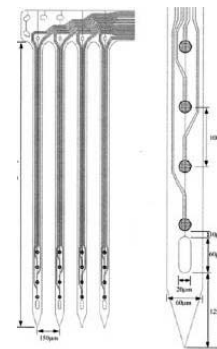


Cyberkinetics Neurotechnology
Systems

Utah Array



Micromachined silicon



Silicon
Michigan Probe

Properties of biomaterials: A comparison

Biological tissues

- Peripheral nerve
 - 600,000Pa (600kPa)
- Muscle
 - 280,000Pa (280kPa)
- Spinal cord
 - 89,000Pa (89kPa)
- Brain
 - 1,000Pa (1kPa)



Substrate materials

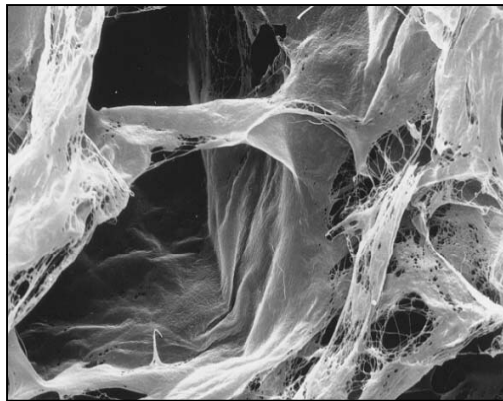
- Silicon
 - 200,000,000,000Pa (200GPa)
 - Rigid
- Polyimide
 - 5,000,000,000Pa (5GPa)
 - Flexible
- PDMS (Silicone)
 - 100,000-10,000,000Pa (0.1-1MPa)
 - Stretchable

Subdural Conformal Array

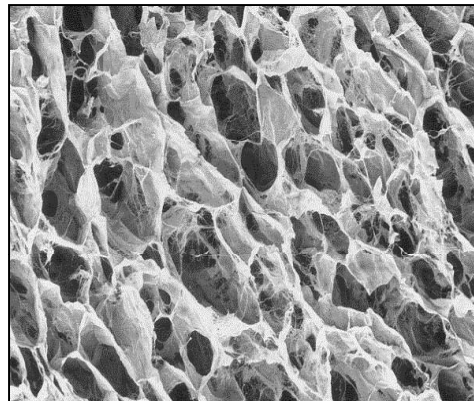


Regenerative properties of collagen

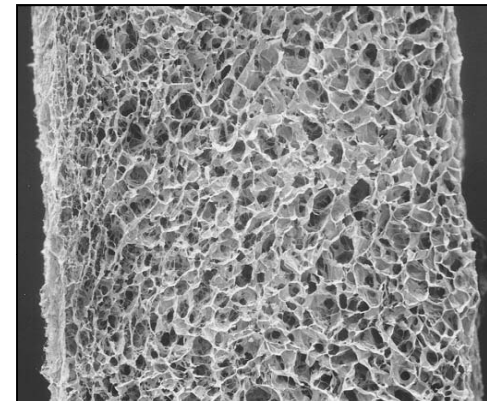
Collagen Matrix pore structure, porosity > 99%, average pore size 80-100 μm .



100 μm



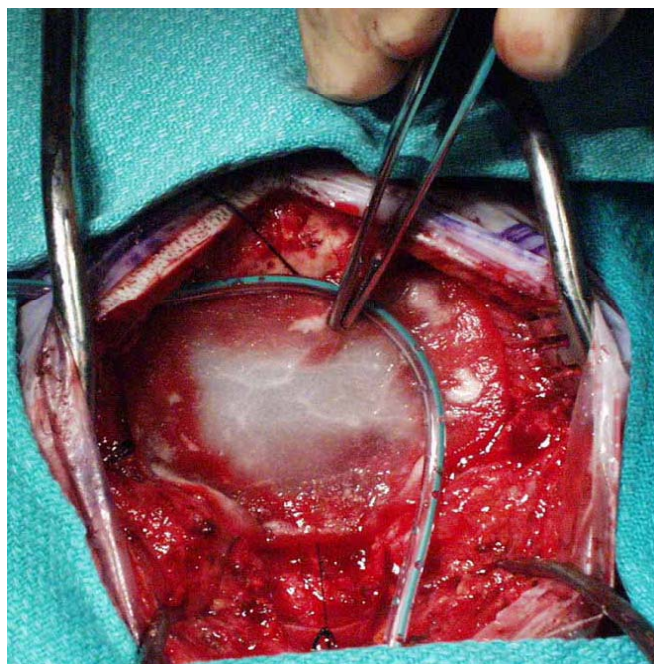
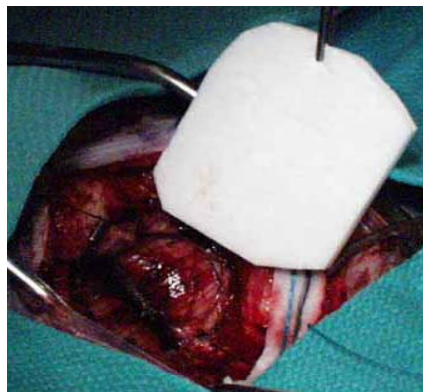
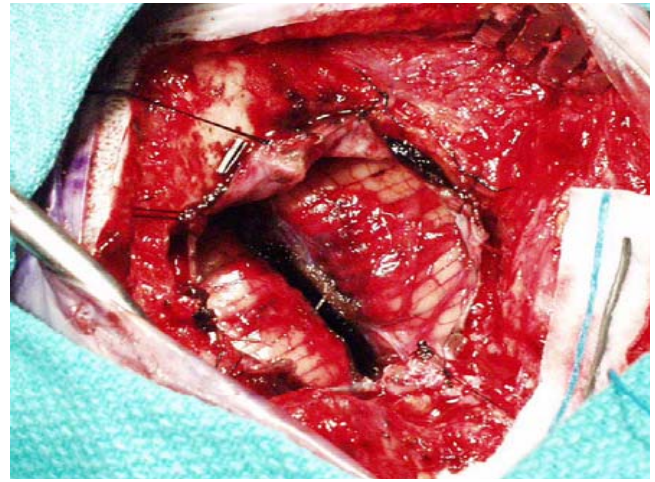
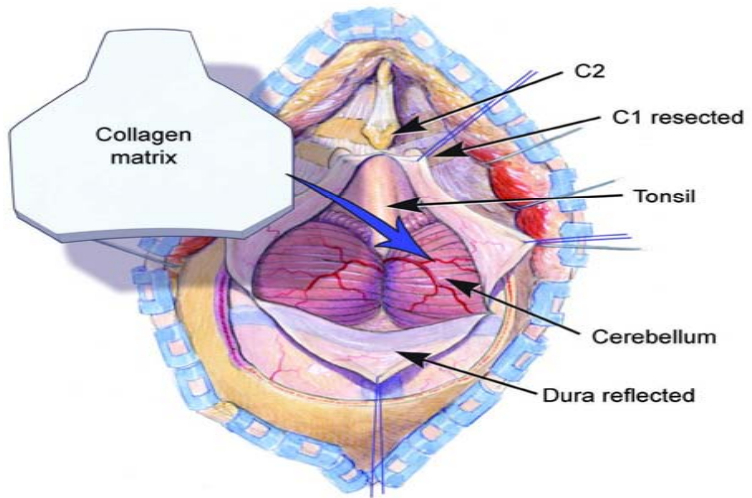
500 μm



1000 μm

- Collagen matrix provides cells with familiar substrate presented in a 3D structure
- Well-suited for use in regeneration of connective tissues

Applications of collagen: posterior fossa duraplasty procedure



Goals for using collagen for interfacing

Goals:

- (1) Recording sites within collagen matrix
- (2) Regenerate tissue disrupted during implantation
- (3) Build device incorporating collagen and recording electrodes
- (4) Measure signal transduction from cells to recording sites

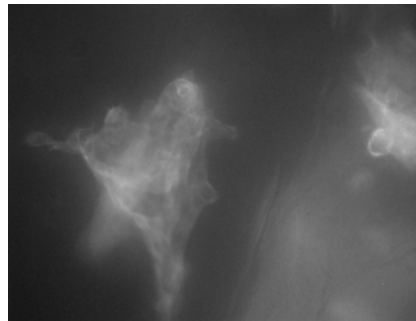
Plan:

Combine materials used to form flexible electronics with materials used in regenerative medicine

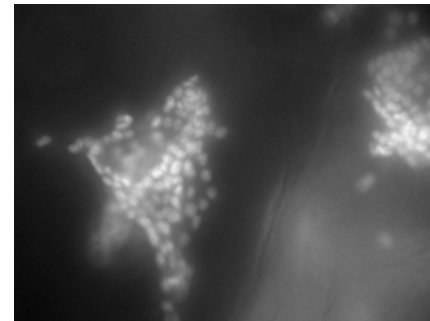
Experiments with collagen matrices: Epithelial cells on collagen

- Mammary epithelial cells growing in collagen matrix
- Cells tend to form three-dimensional structures in the collagen
- Figure *a*: actin filaments
- Figure *b*: nuclei
- Figure *c*: combination of *a* and *b*

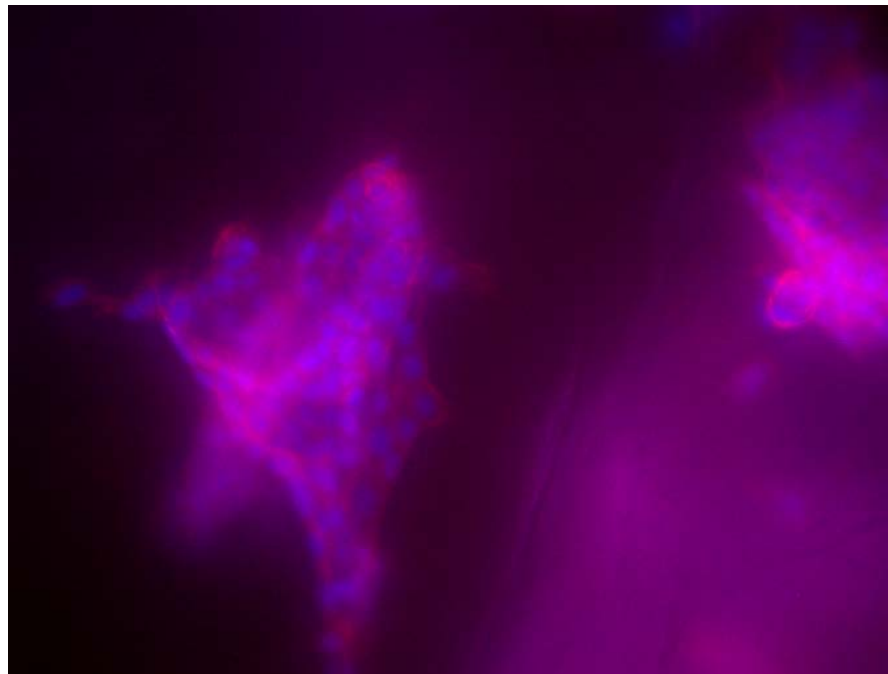
a.



b.



c.



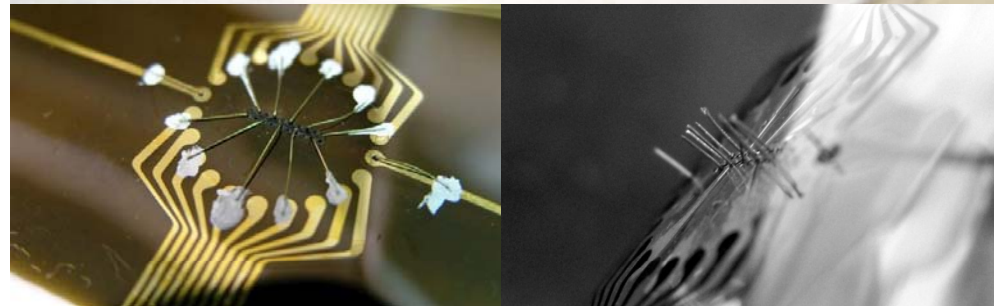
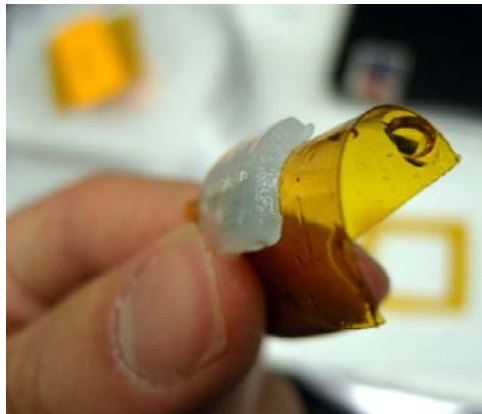
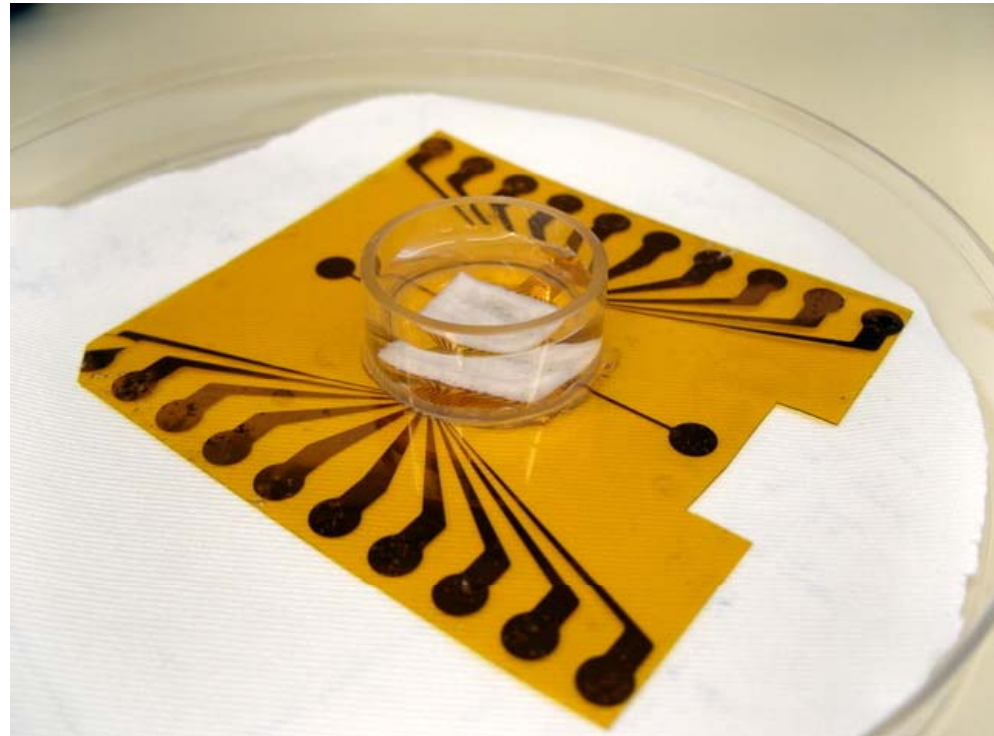
Electrode fabrication and assembly

- **Connecting the electrodes**

- electrodes are bent, then electrically and mechanically silver paste and PDMS

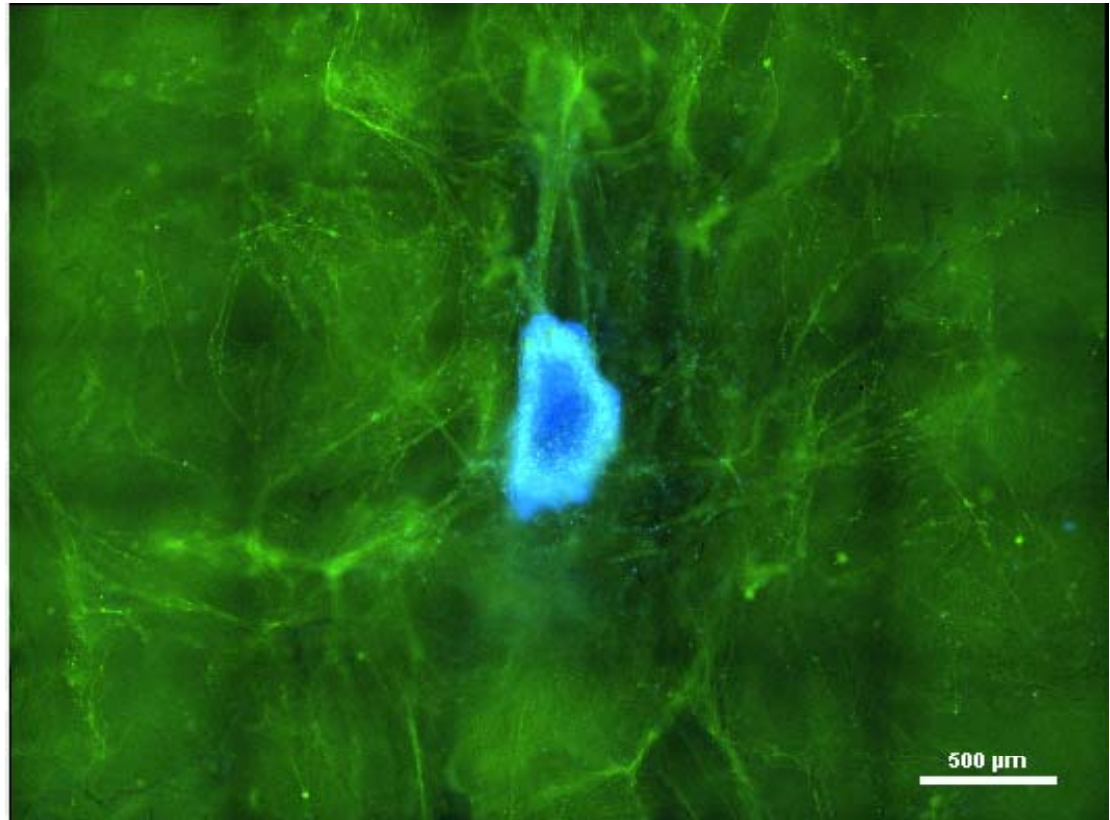
- **Collagen Layer**

- electrodes puncture collagen sheet and PDMS layer soaks into and cures within collagen, securing the collagen to the backplane.



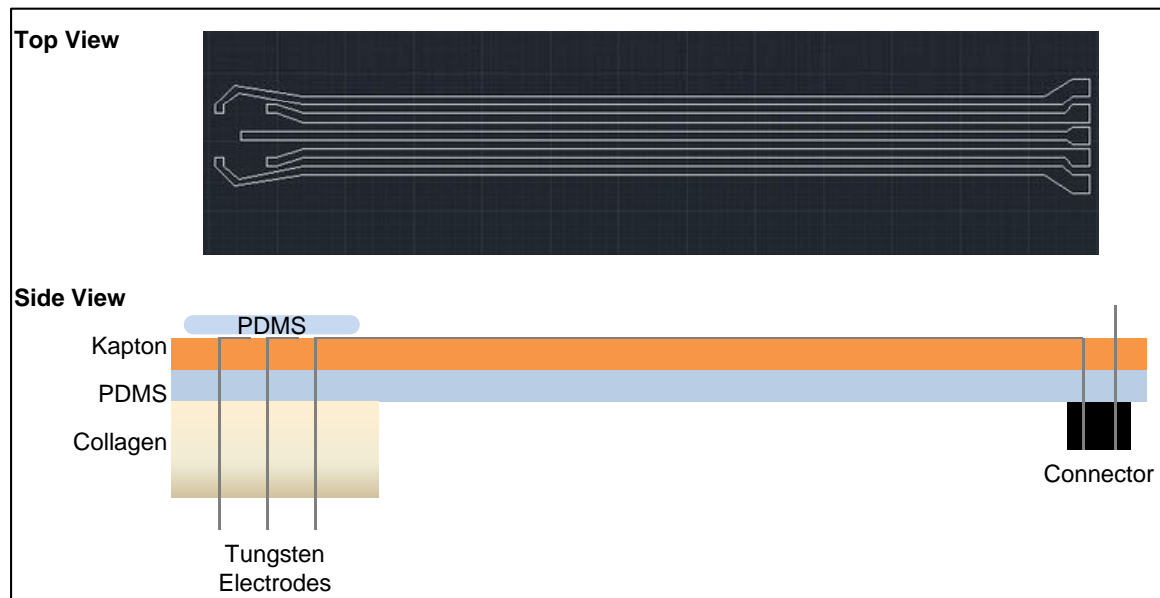
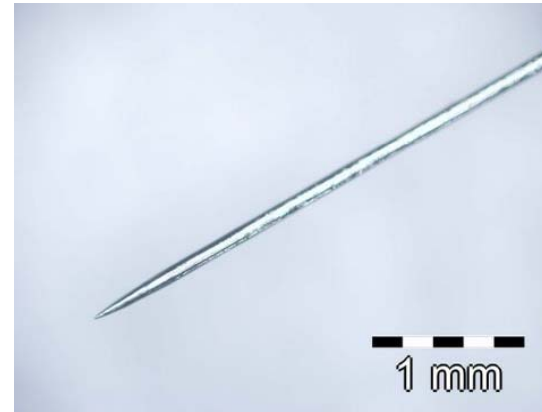
Experiments with collagen matrices: Explanted neurons

- Image of the SCG explant taken after 20hrs of labeling
- Cells were stained with Hoescht (blue) and DiO (green) to visualize nuclei and cellular membranes
- The green web is the axon network extending from the cell bodies in the center



Electrode fabrication and assembly

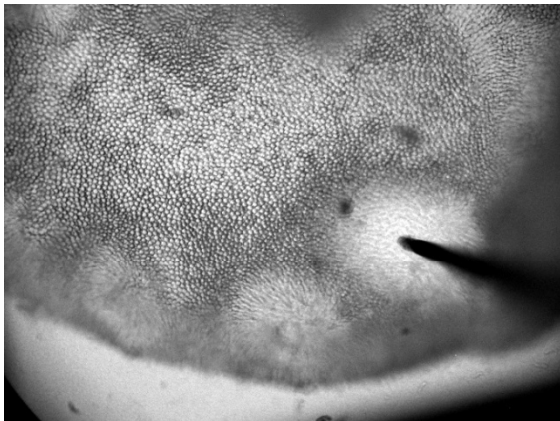
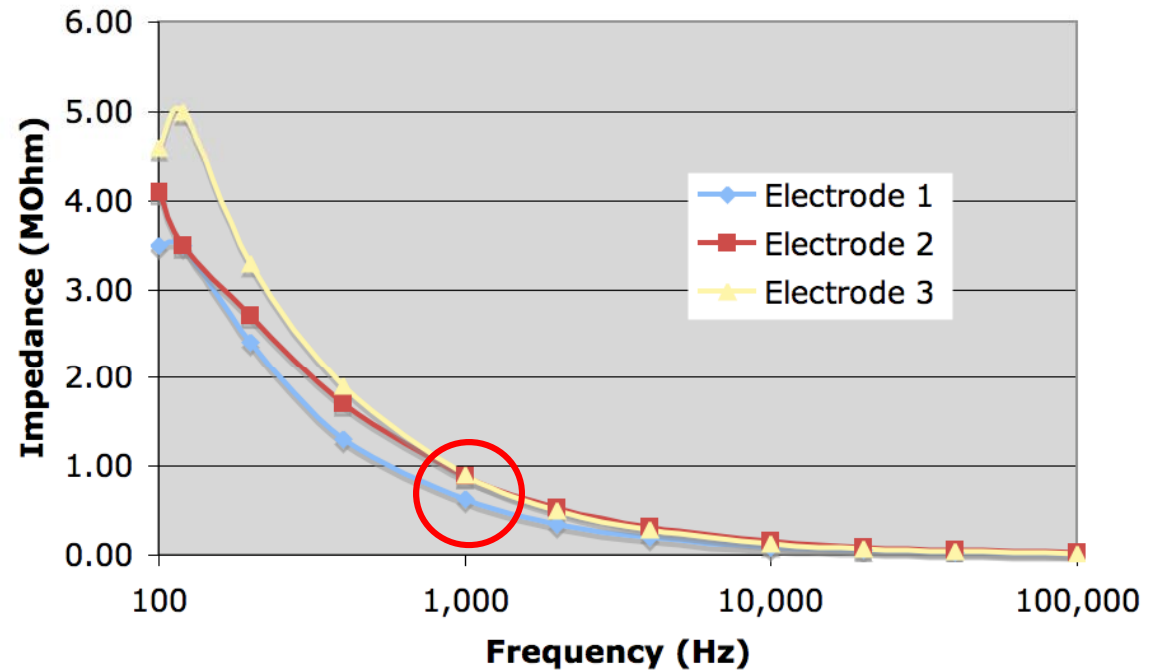
- **Electrode sharpening**
 - electrolytic sharpening in potassium nitrite (KNO_2) solution
- **Electrode insulation**
 - electrophoretic paint
- **Backplane**
 - laser-drilled holes for electrodes
 - thin film gold traces for contacts



Experiments with electrodes

Impedance

At 1 kHz, electrodes have impedance of approximately 1 MOhm



Recording

Record electrophysiology of salamander retina tissue

Conclusions and outlook

- Recording sites within collagen matrix
- Regenerate tissue disrupted during implantation
- Combine microfabrication with collagen to significantly improve both *in vitro* and *in vivo* recording devices

Questions