

# Microelectrode Arrays for Clinical Mapping: Considerations and Brain Recordings with 1024 Channel Arrays

*A subset of slides presented in the symposium has been removed pending publication*

Shadi A. Dayeh

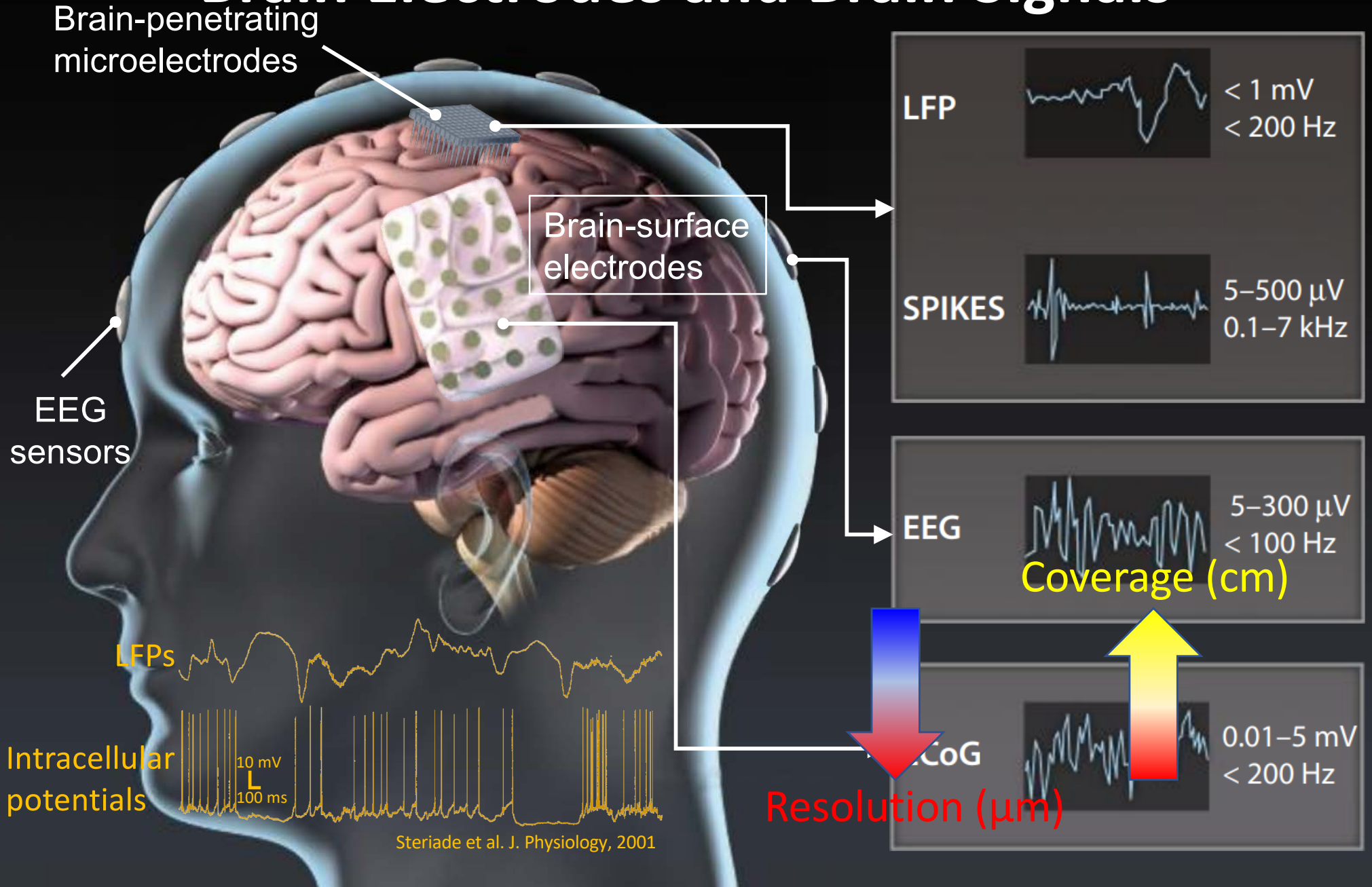
Integrated Electronics and Biointerfaces Lab  
Department of Electrical and Computer Eng.

University of California San Diego

[sdayeh@eng.ucsd.edu](mailto:sdayeh@eng.ucsd.edu)

<http://iebl.ucsd.edu/>

# Brain Electrodes and Brain Signals



# Use of Brain Mapping Devices

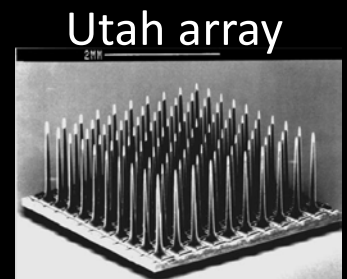
## 1. Diagnostic: Clinical Mapping During Neurosurgery

- Intractable epilepsy → delineation of the epileptic zone
- Tumor resection



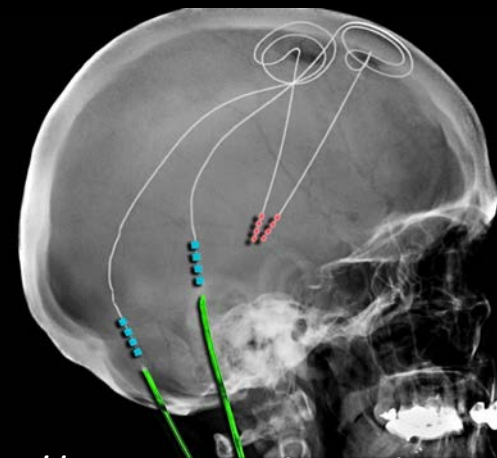
## 2. Therapeutic: Neuroprosthesis; Cortical Interface prosthesis

- Motor function disability
- Speech disorders, etc.



Hochberg et al., Nature 485, 372, 2012.

Movement disorders (Parkinson's disease)



# State of the art Brain Electrodes

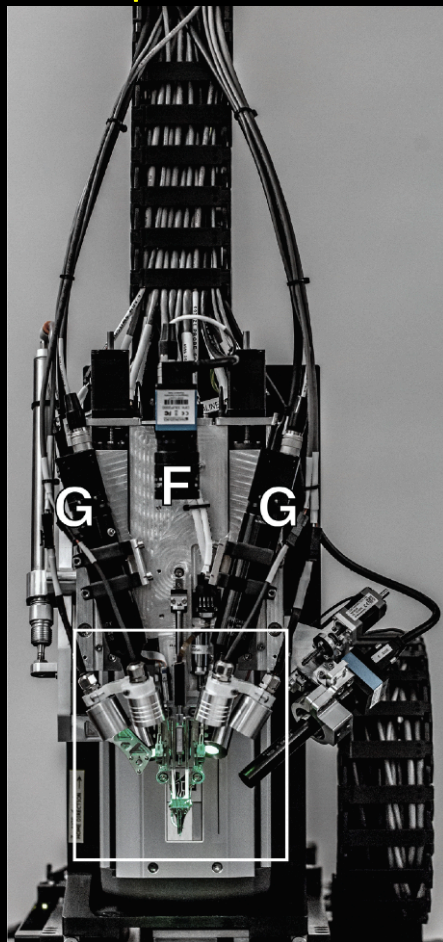


# Neuralink: An integrated brain-machine interface platform with thousands of channels

- Developing ultra-high bandwidth brain-machine interfaces.
- Elon Musk: Goal is to achieve “symbiosis with artificial intelligence.”
- Silent speech communications.



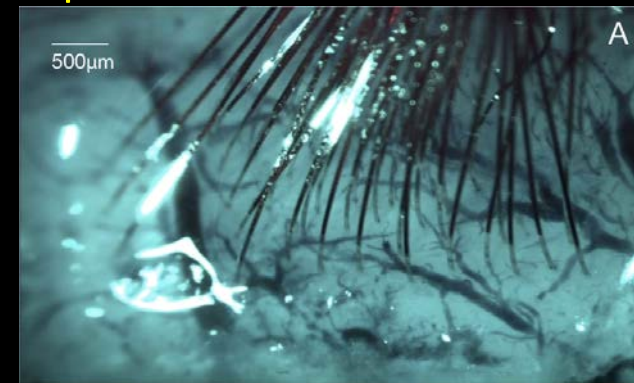
Implanter robot



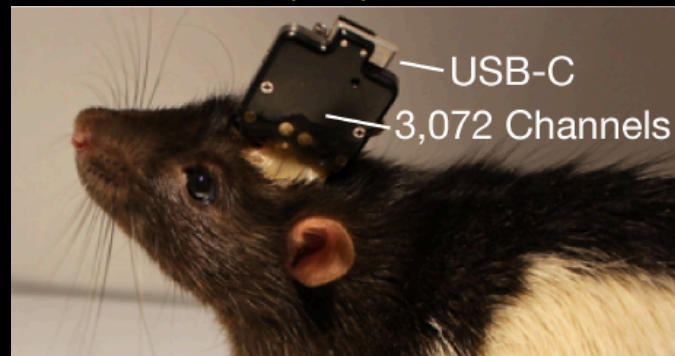
Threads



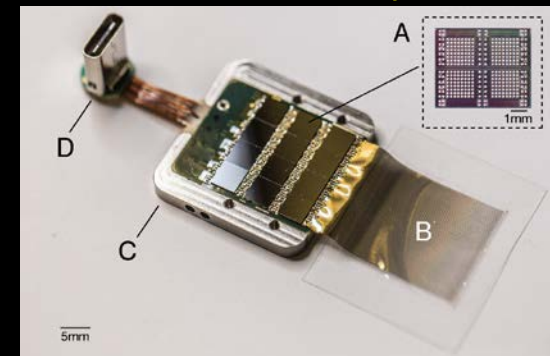
Implanted in a mouse cortex



Mouse preparation

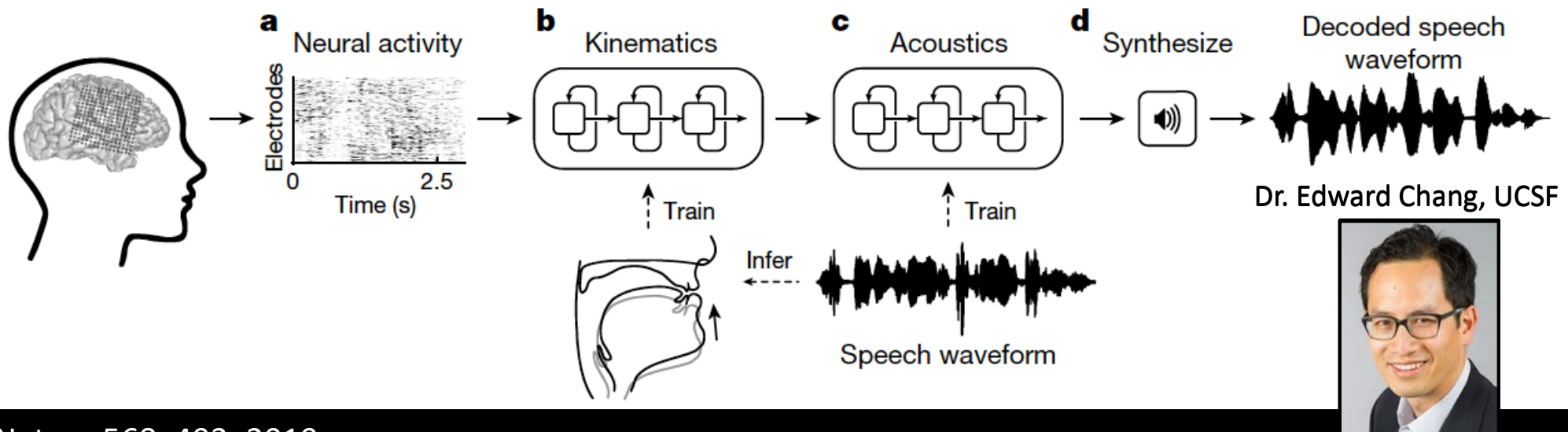


Device Assembly



Human trials are expected in Fall of 2020.

# Silent Communication “Speech disorders”



Nature 568, 493, 2019

## Facebook

A diffuse optical tomography headset

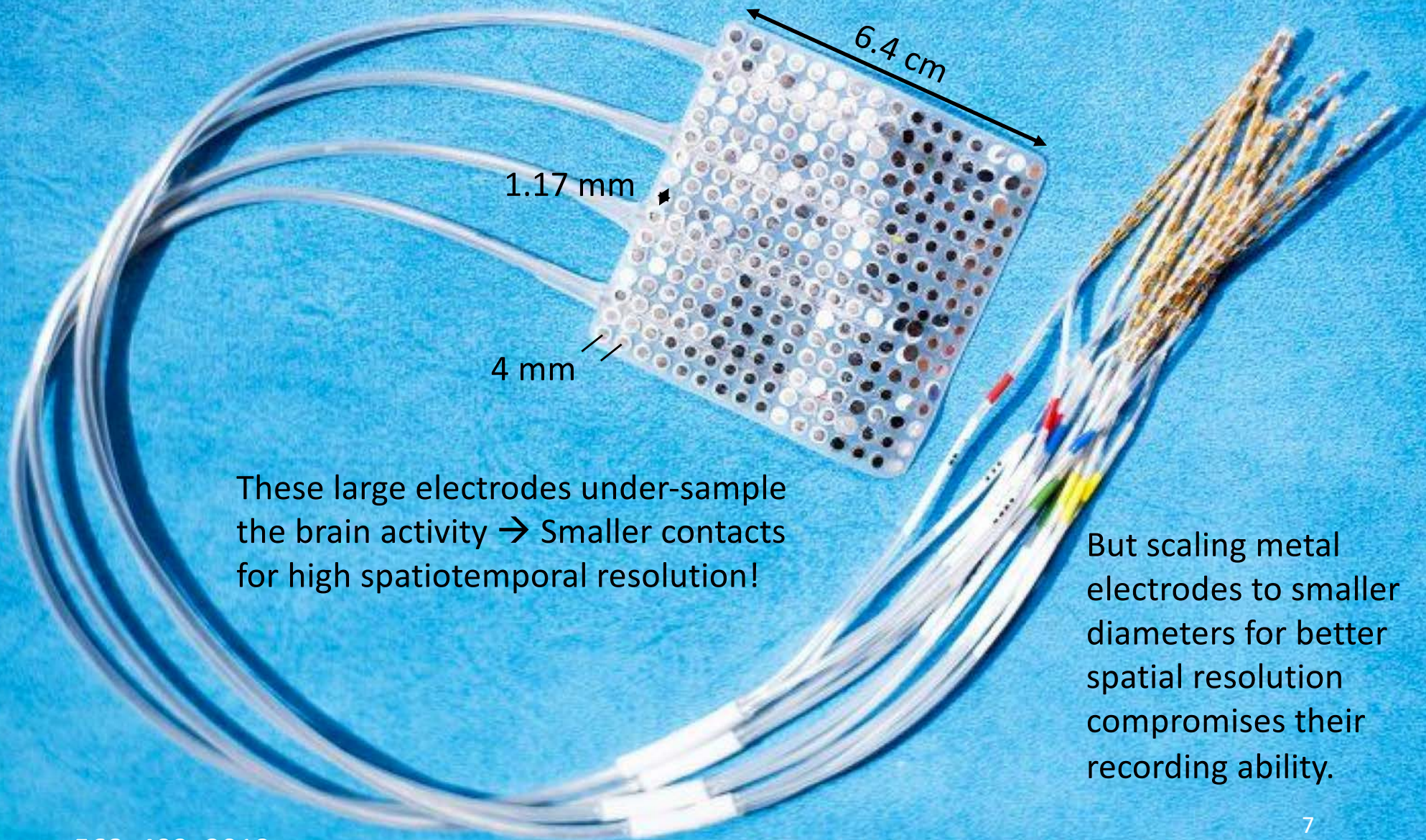


- Concept is to use near-infrared light to measure oxygen saturation levels in the brain.
- By mapping blood oxygen levels to specific brain regions, phonemes, or intent for motor movements could be decoded.



# State of the Art Clinical Mapping Device

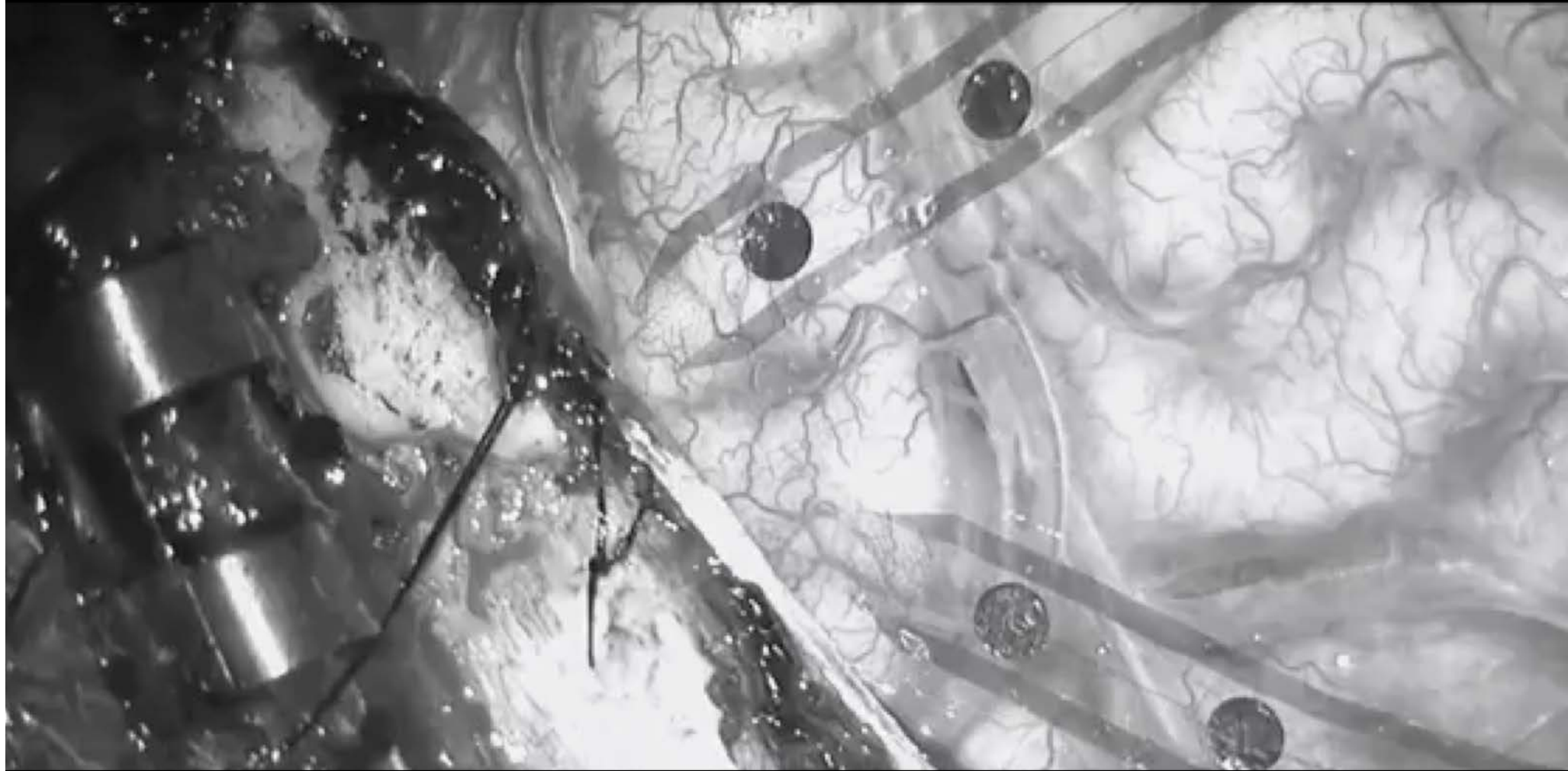
AdTech Inc., 256 ch clinical grid



These large electrodes under-sample the brain activity → Smaller contacts for high spatiotemporal resolution!

But scaling metal electrodes to smaller diameters for better spatial resolution compromises their recording ability.



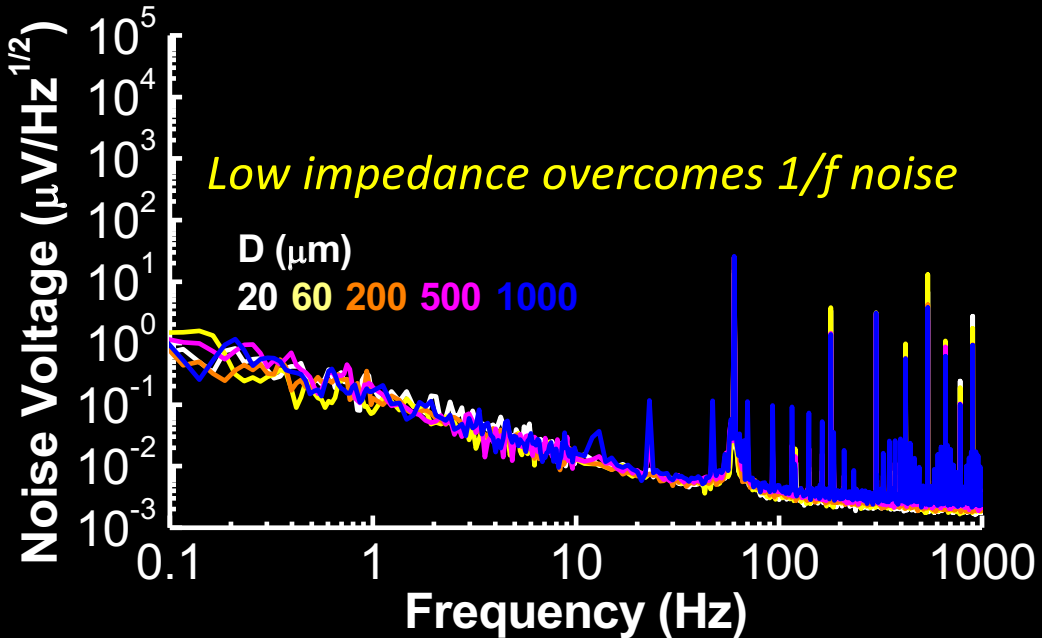
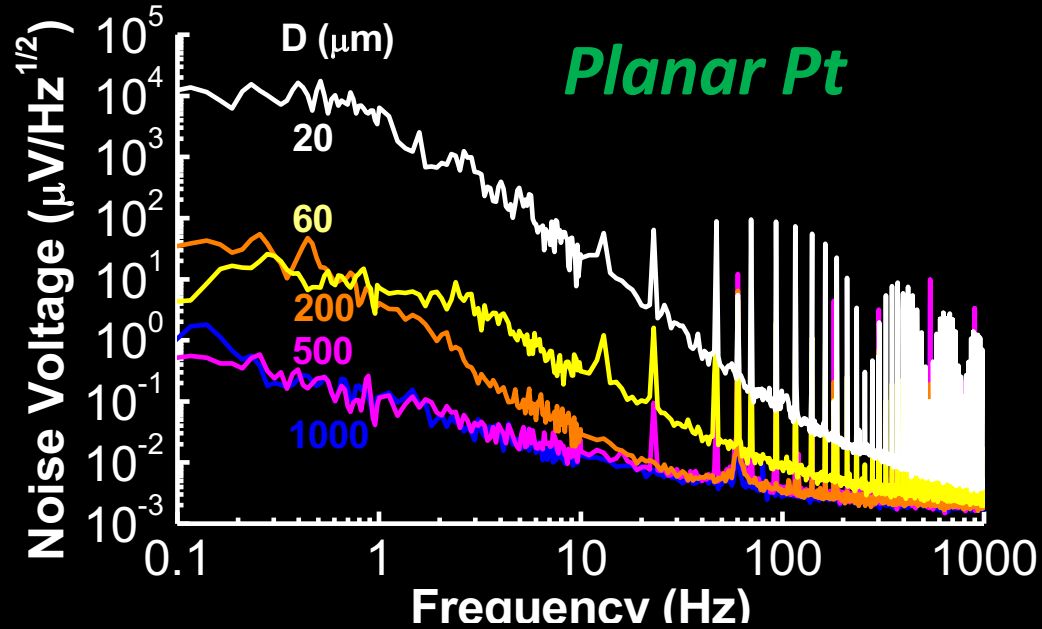


## Thin Electrodes:

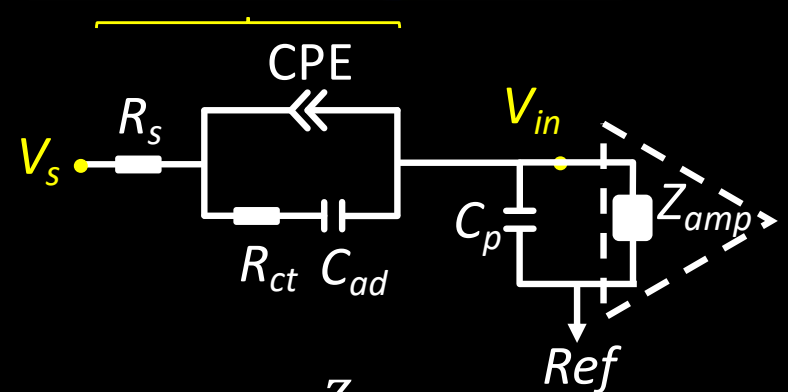
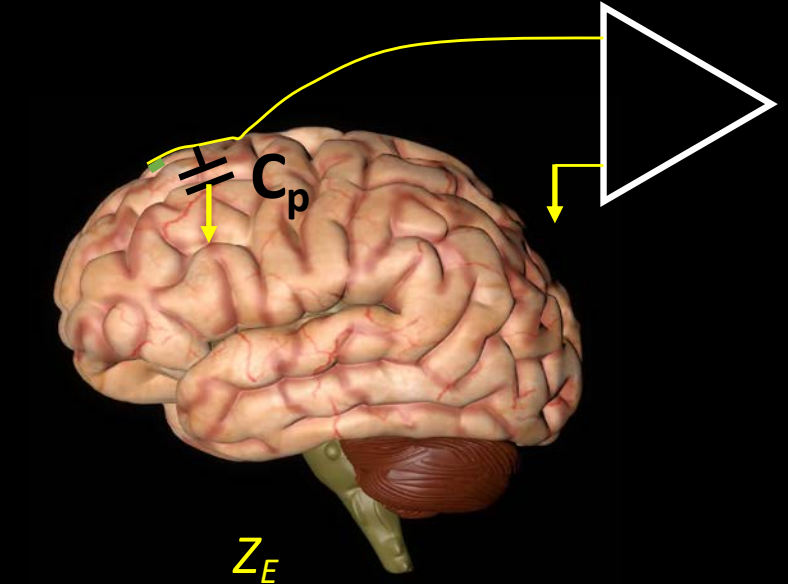
- Compliant
- Conformal.
- Intimate contact.

# Why Impedance Matters for Recording

1. High spatial resolution → scaling → noise



2. Large area coverage → parasitic shunting → attenuation

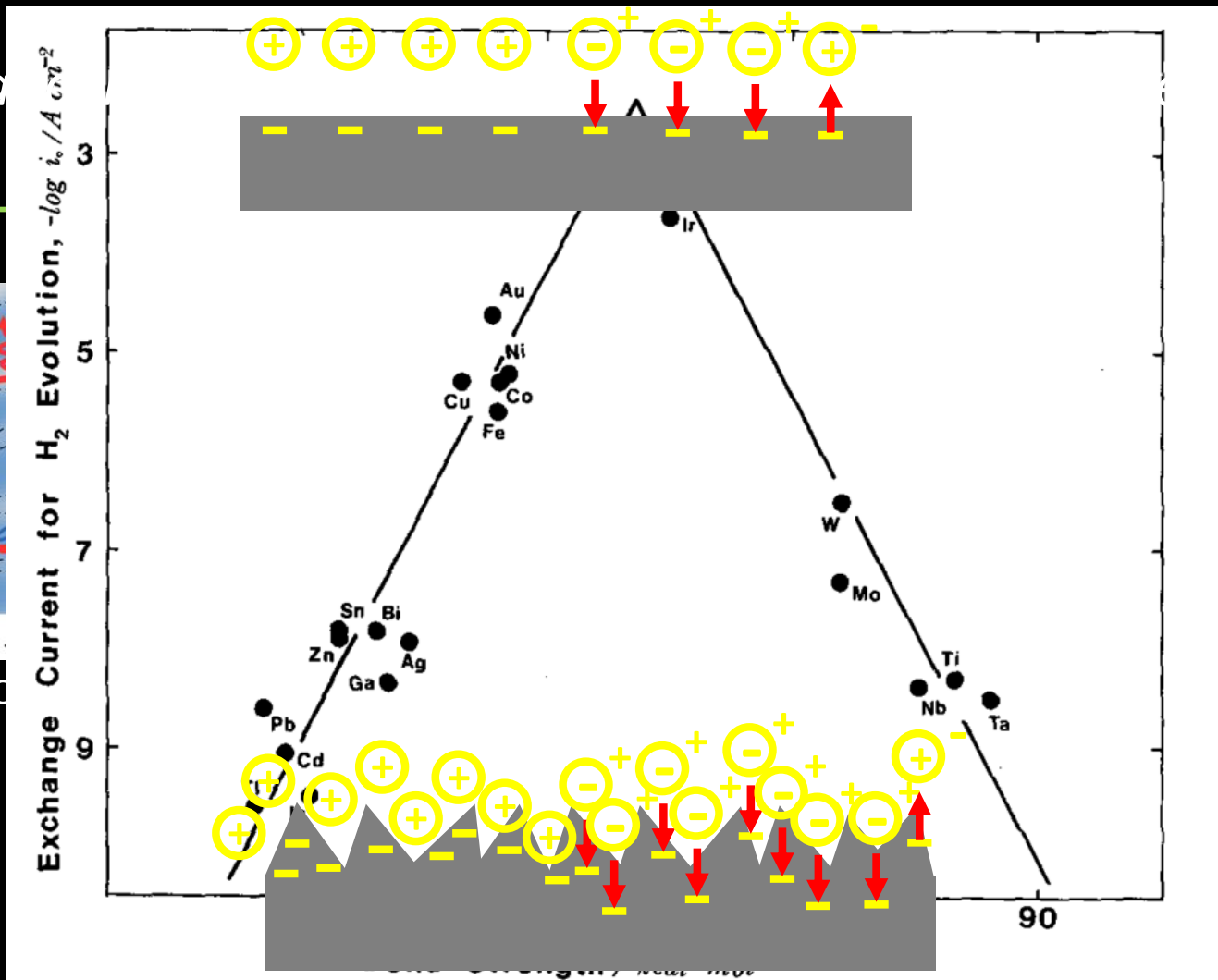


$$V_{in} = \frac{Z_{amp}}{Z_{amp}[(j\omega C_p)Z_E + 1] + Z_E} V_s$$

If  $C_p$  is large,  $Z_E$  should be small

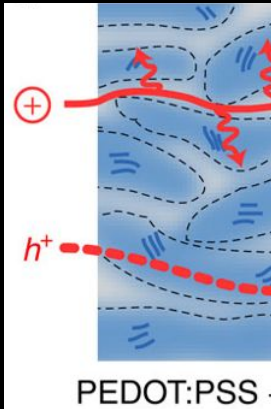
# 'Everything is the Interface': Electrodes

**Volcano Plot:** Electrochemical activity vs. bond energy

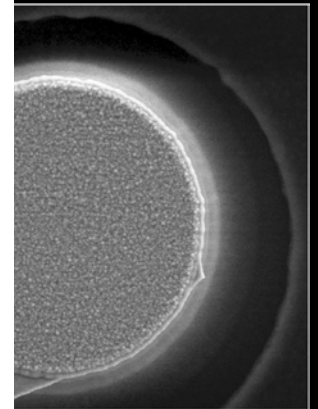


Trasatti et al. J. Electroanalytical Chemistry 39, 163, 1972.

Surface catalytic property and surface area are both important.



Rivnay et al. Nat. C



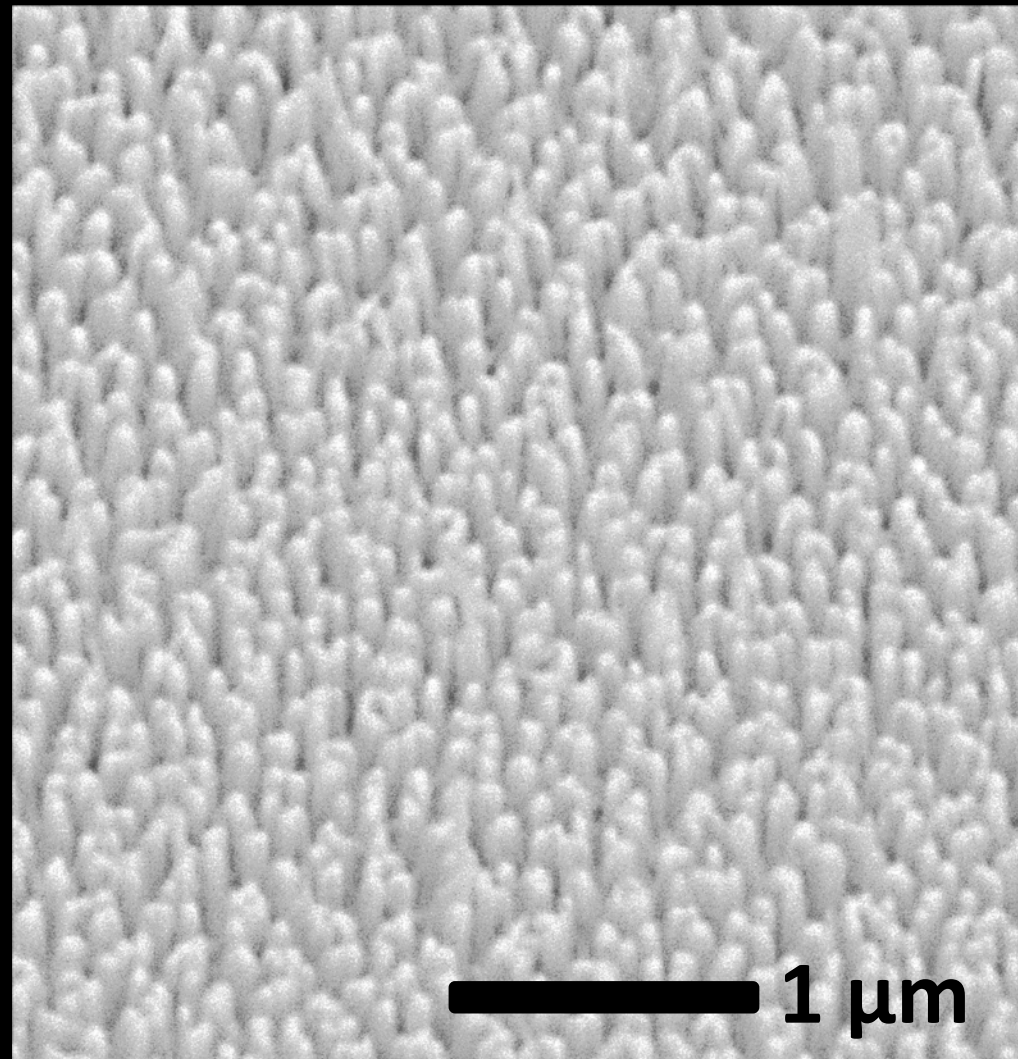
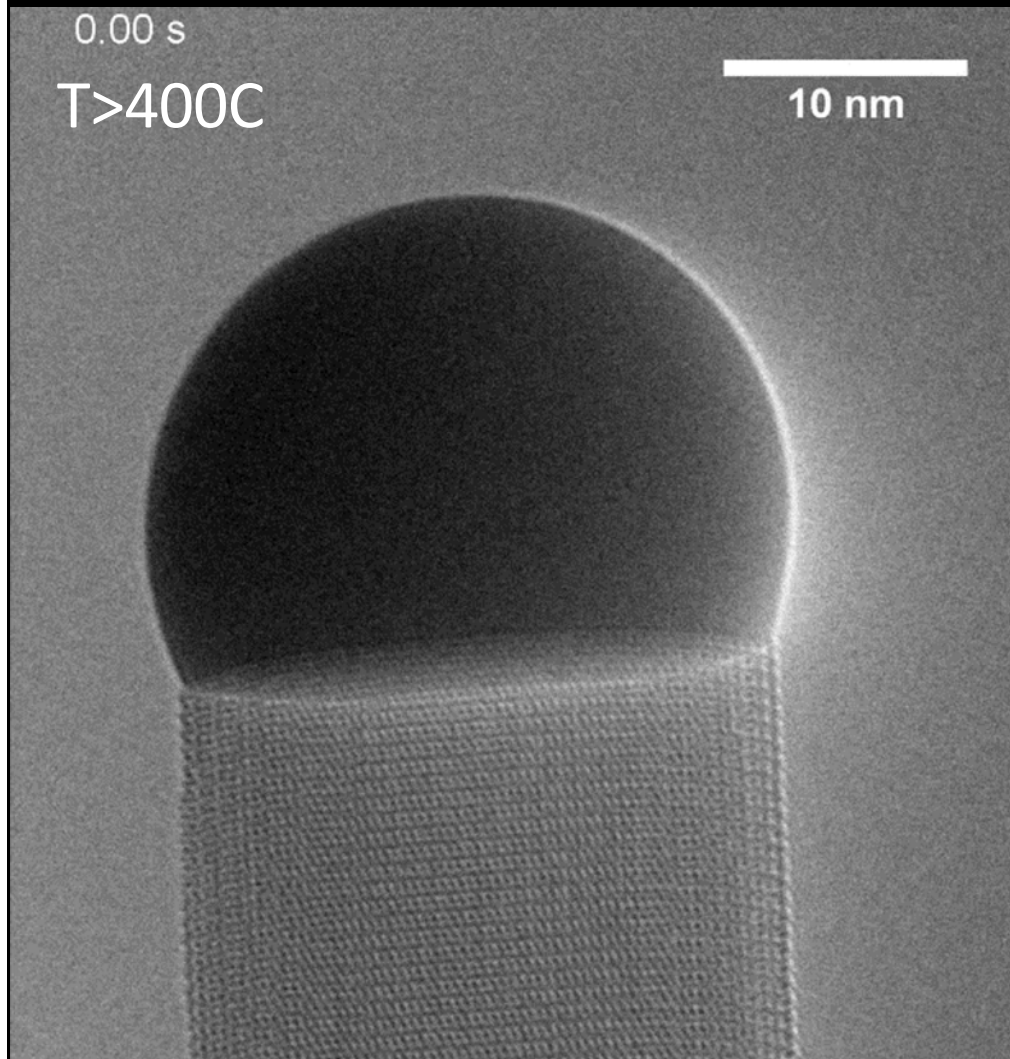
nt. MEA meeting, 2008



# Outline

- ❖ Pt Nanorod (PtNR) surface microelectrode arrays.
  - Structure and electrochemical properties.
- ❖ Intraoperative Monitoring:
  - Epilepsy monitoring.
  - ~~Language mapping.~~
  - ~~Functional boundaries.~~
- ❖ ~~Spinal Cord Implants for Pain and Restoring Motion.~~

# 1D Materials on Flexible Substrates

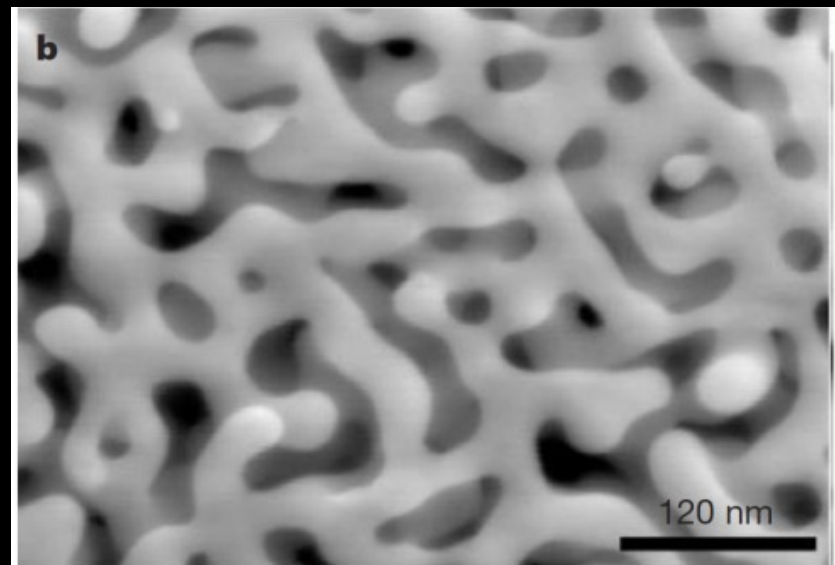
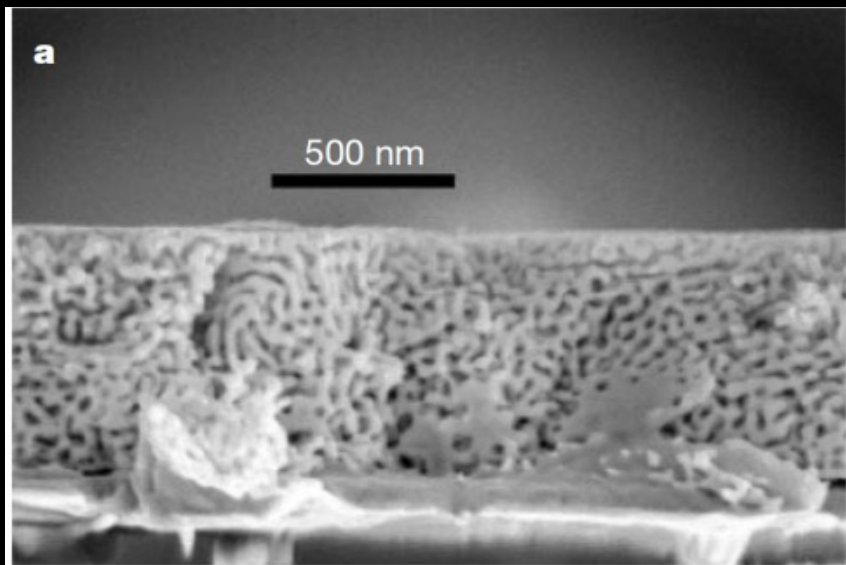


Harmand et al. Phys. Rev. Lett. **121**, 166101, 2018

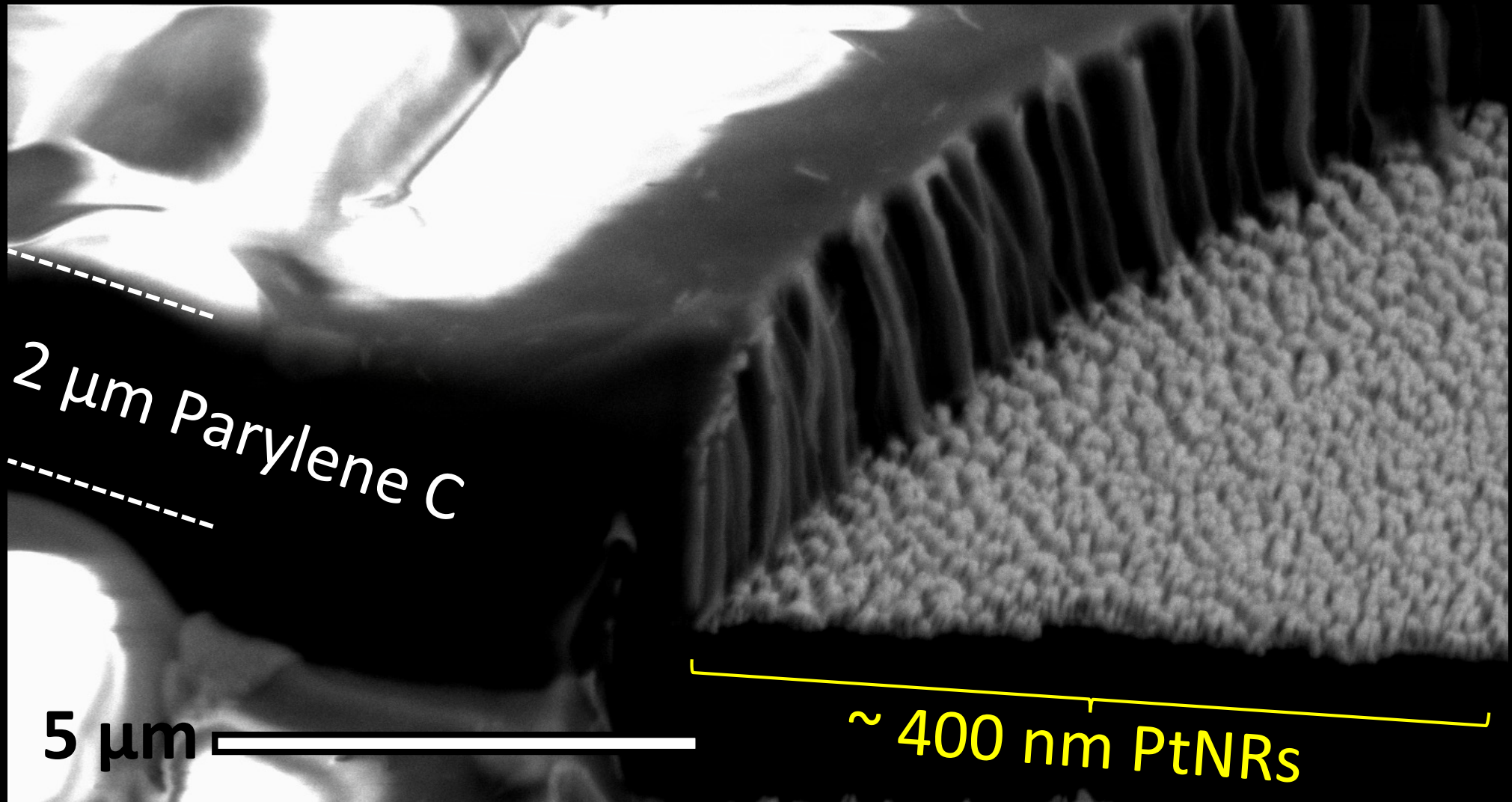
This work: Pt nanorods

# Pt Nanorod Electrodes

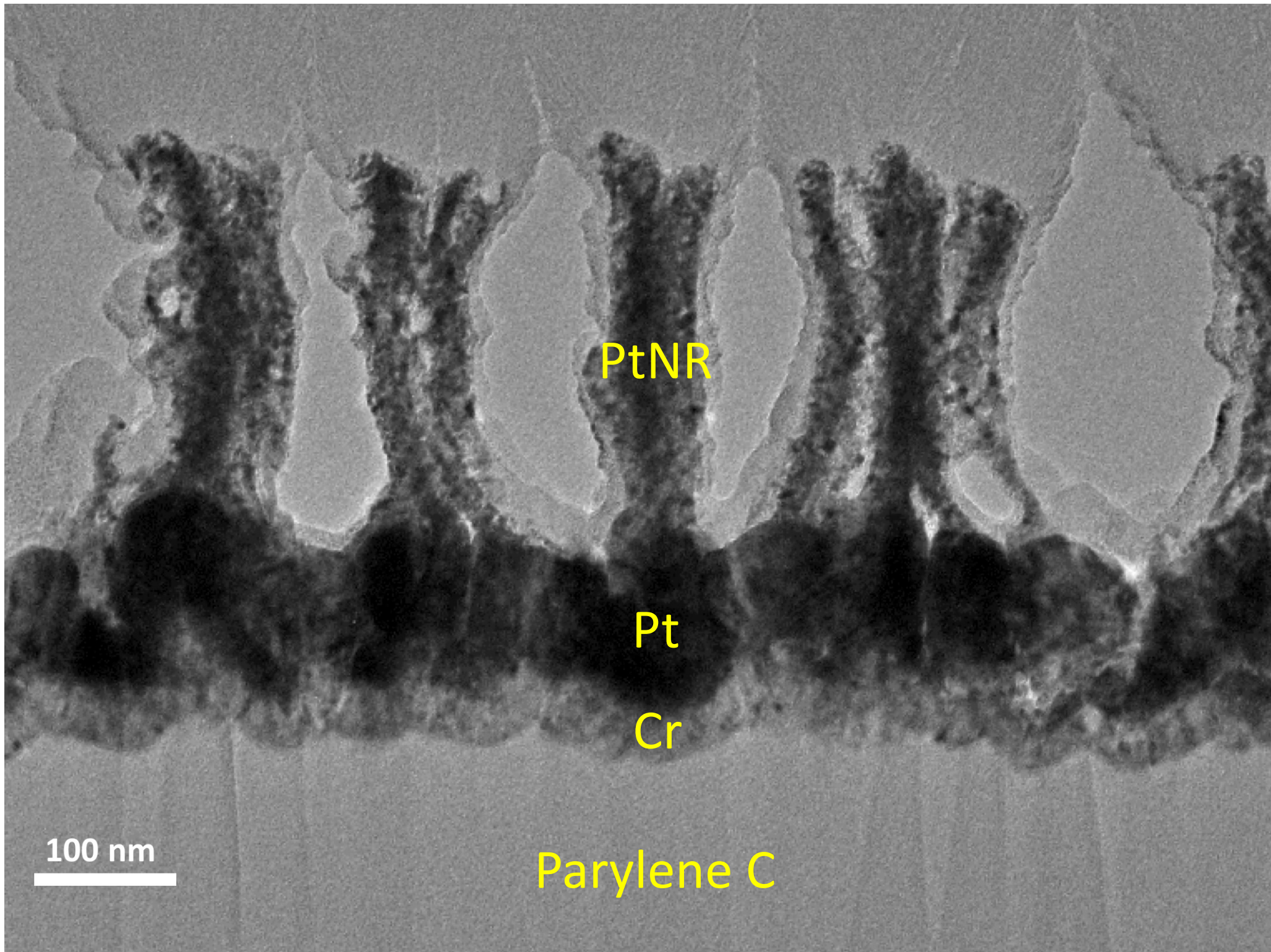
- Dealloying: Selective dissolution of alloys to a **stable** nanoporous structure.



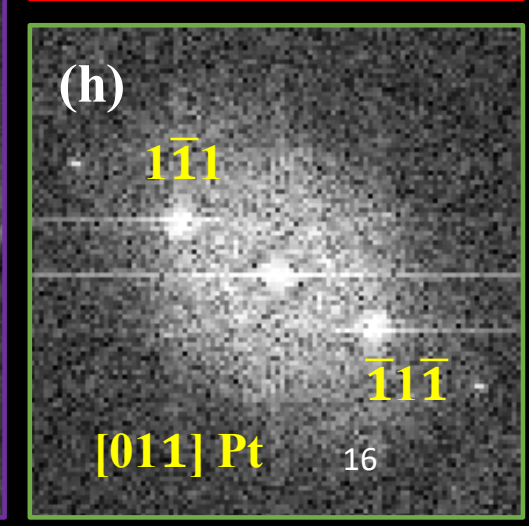
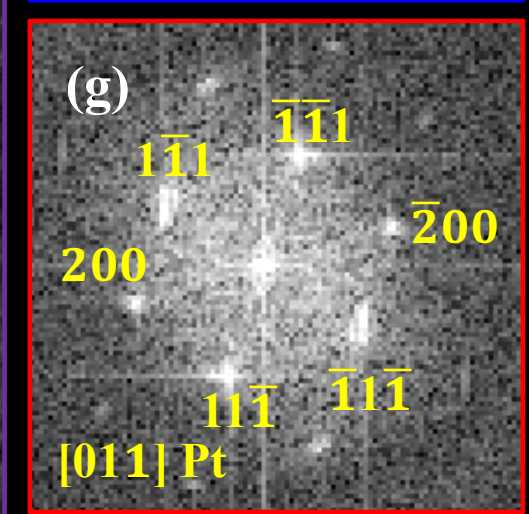
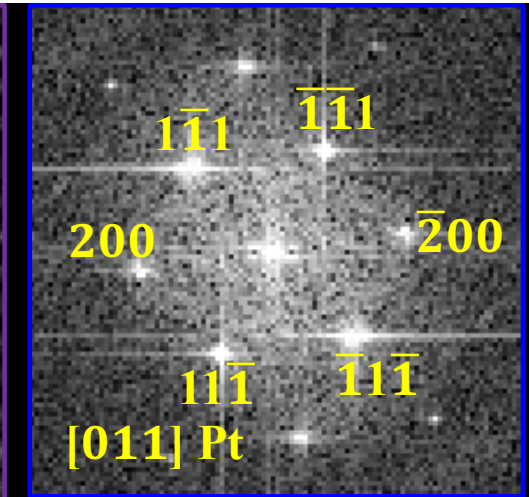
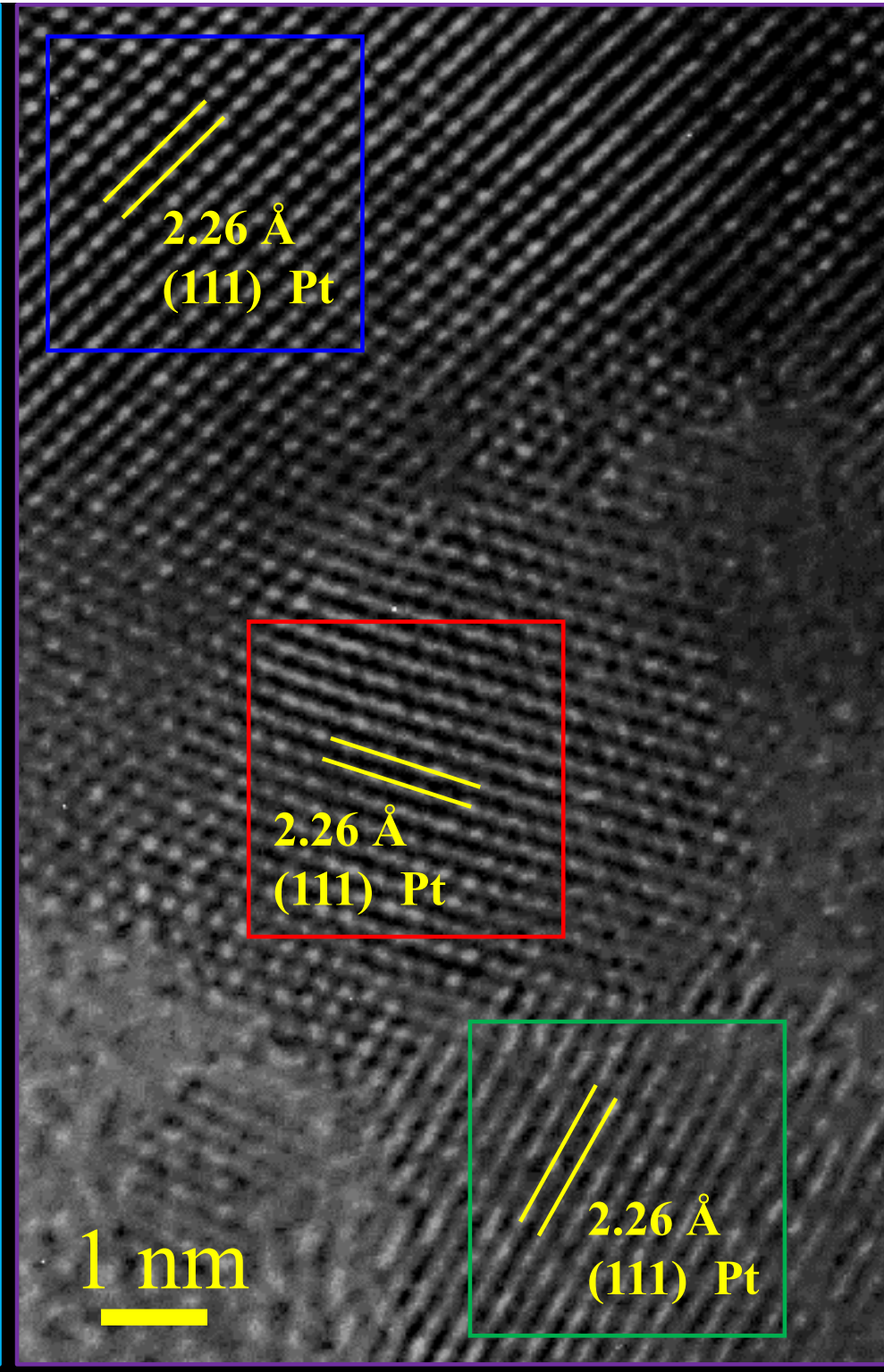
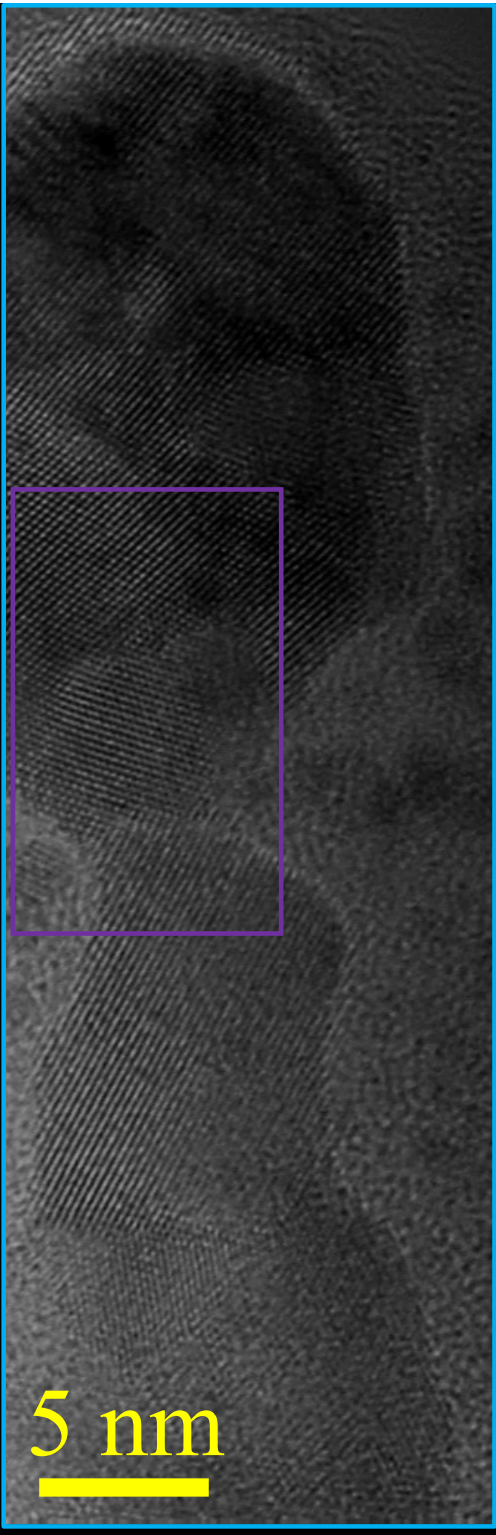
# Pt Nanorod Electrodes





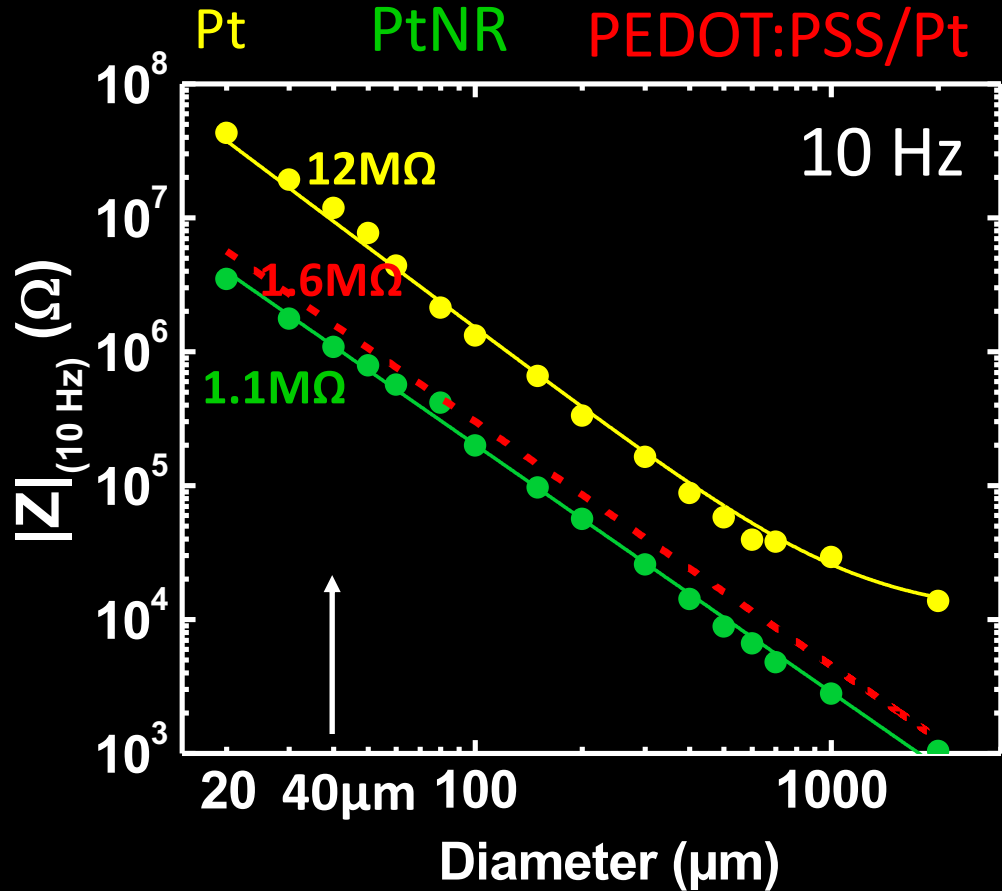






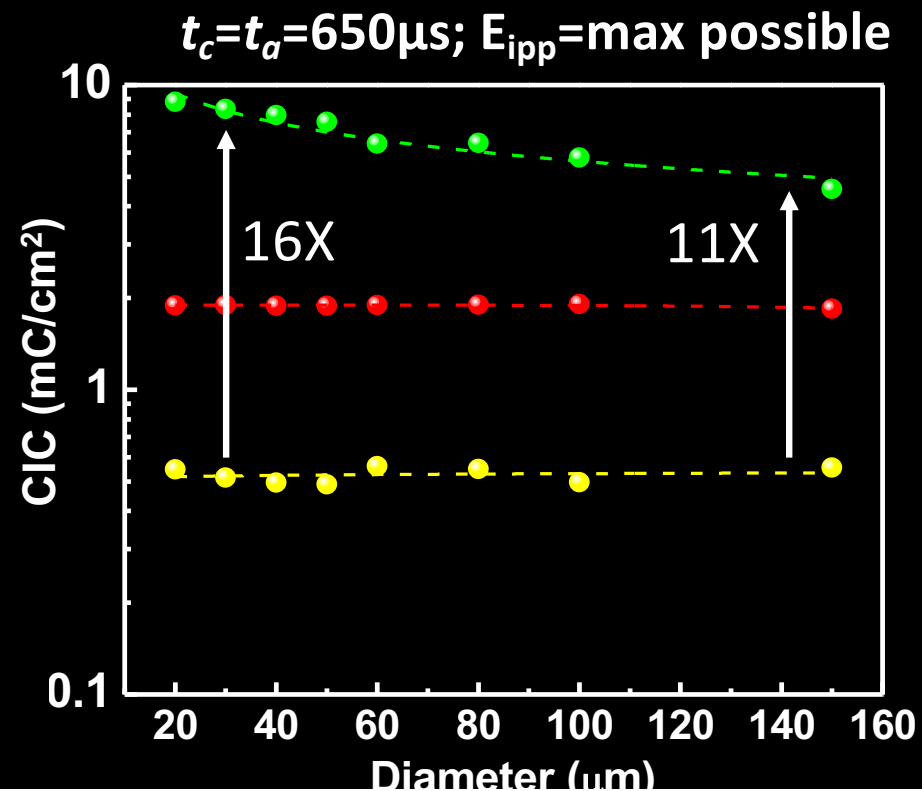
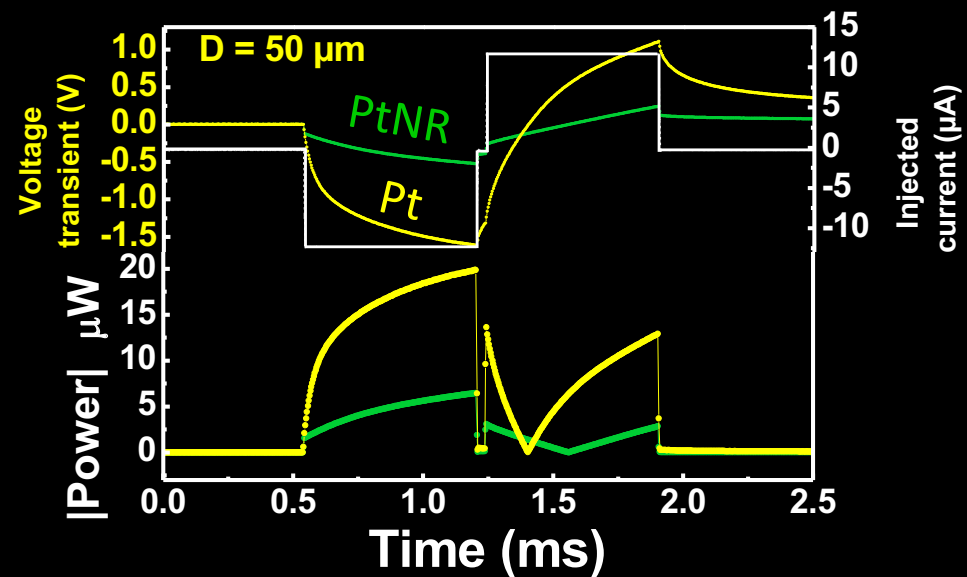


# Electrochemical Properties of PtNRs



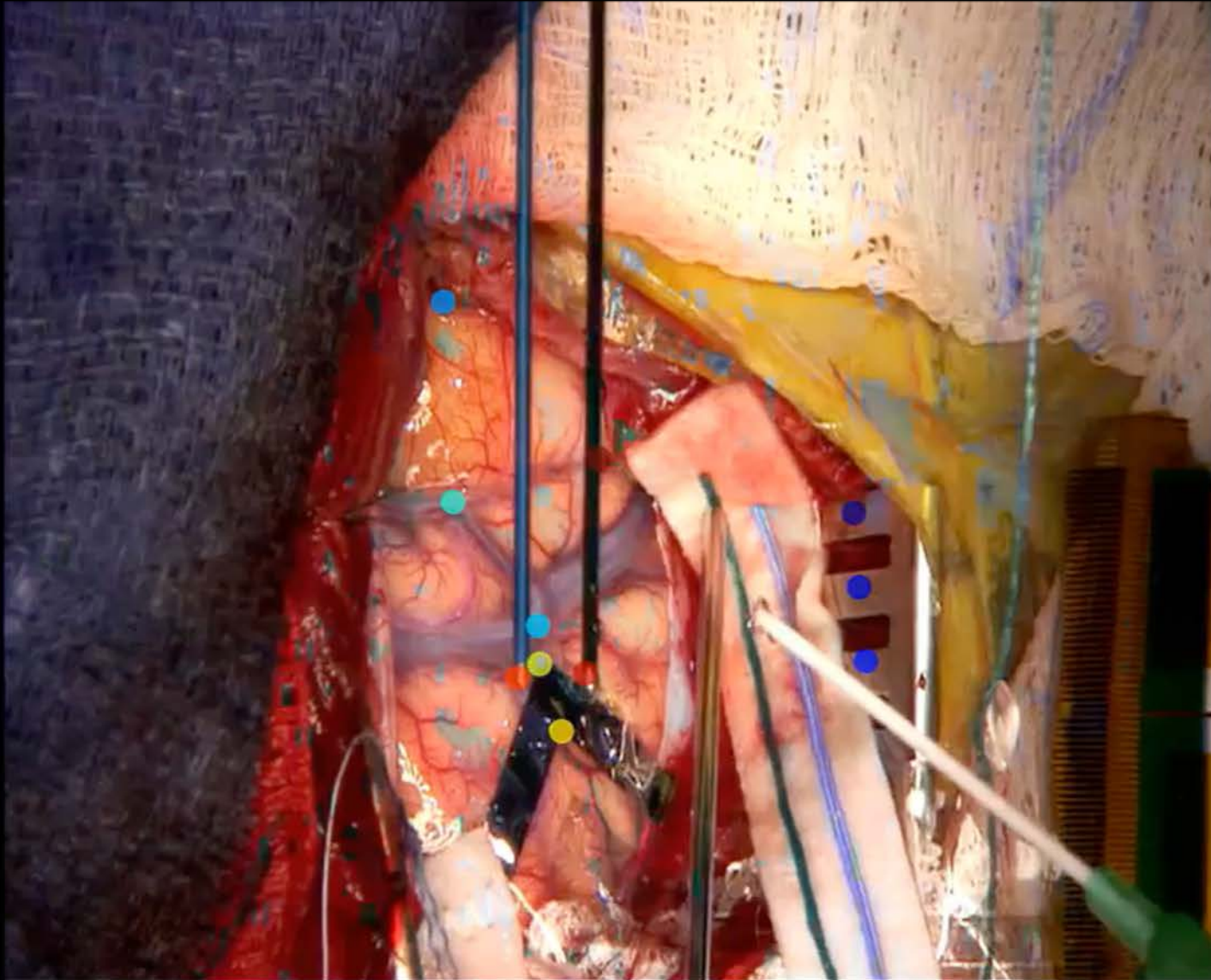
- Low impedance  $\rightarrow$  low noise and better stimulation characteristics.
- Smaller voltage transients on PtNRs  $\rightarrow$  Lower power dissipation for an implant that uses PtNRs.

M. Ganji et al. Nano Lett. 19, 6244, 2019.

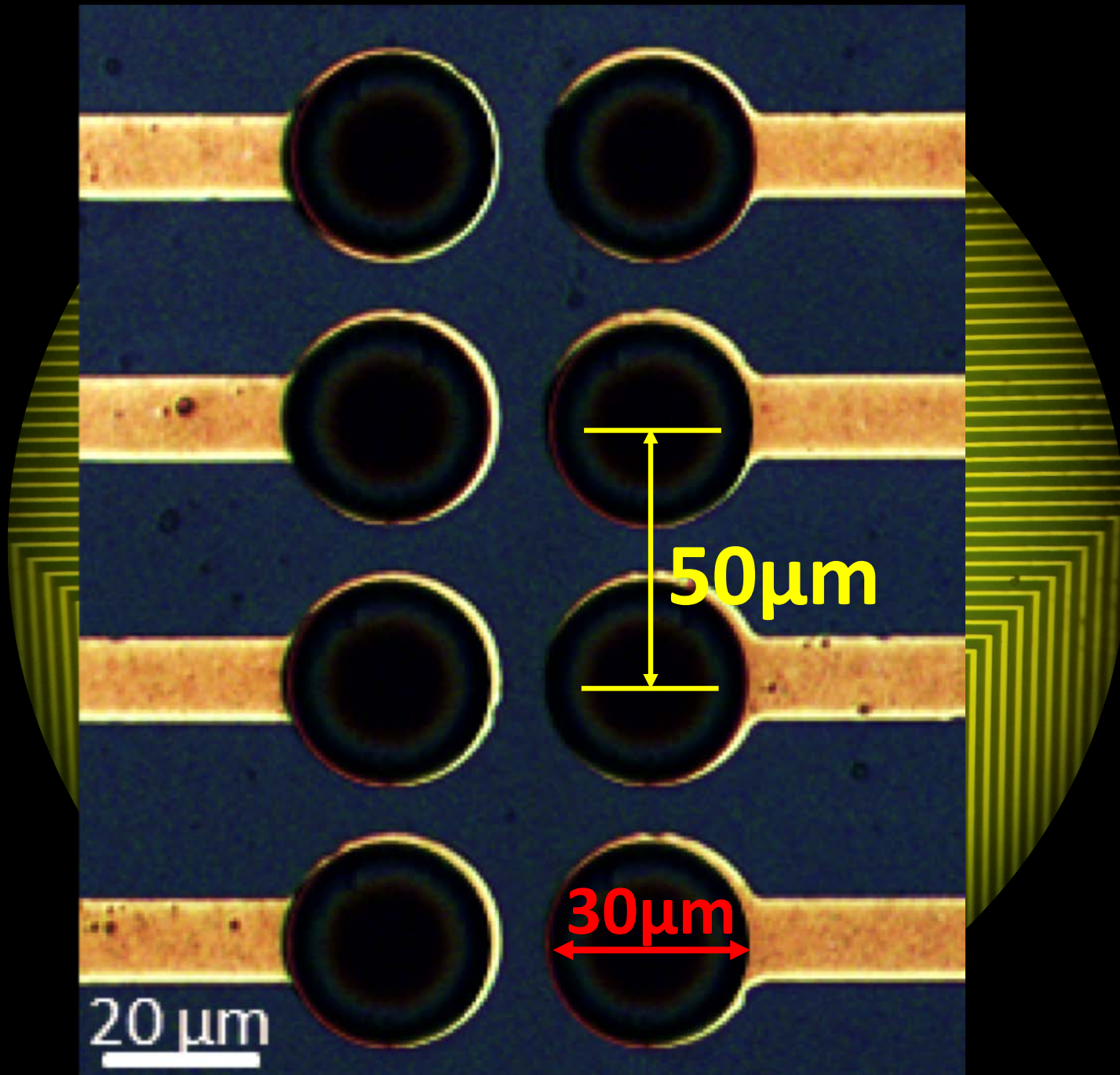


# Intraoperative Neuromonitoring

## Audio / video and automated object tracking

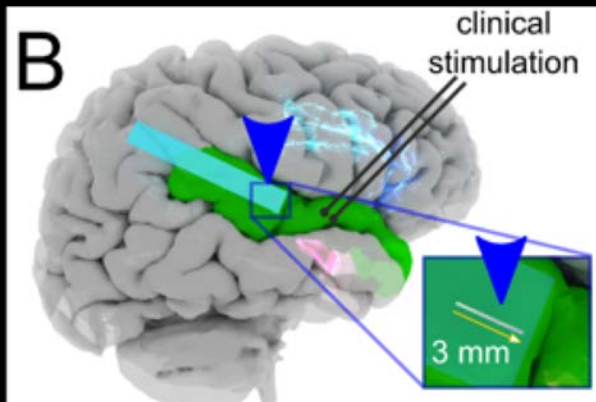


# Small Pitch $\mu$ ECoG Array

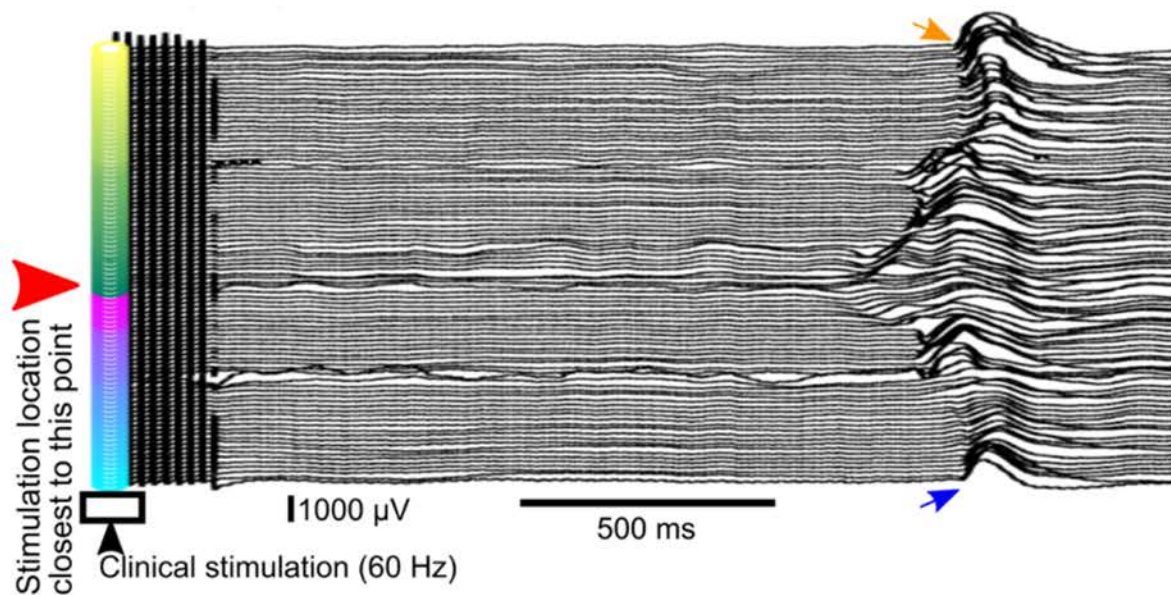




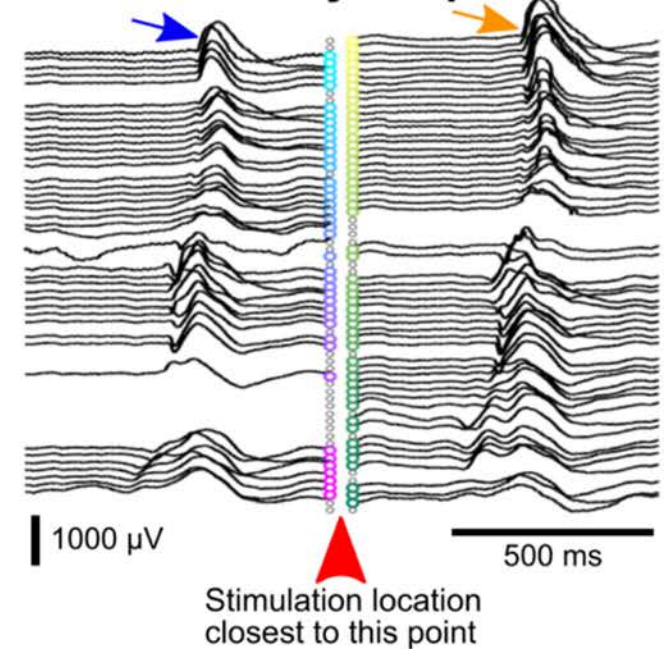
# Recording Traveling Waves from the Human Brain



Activity in time

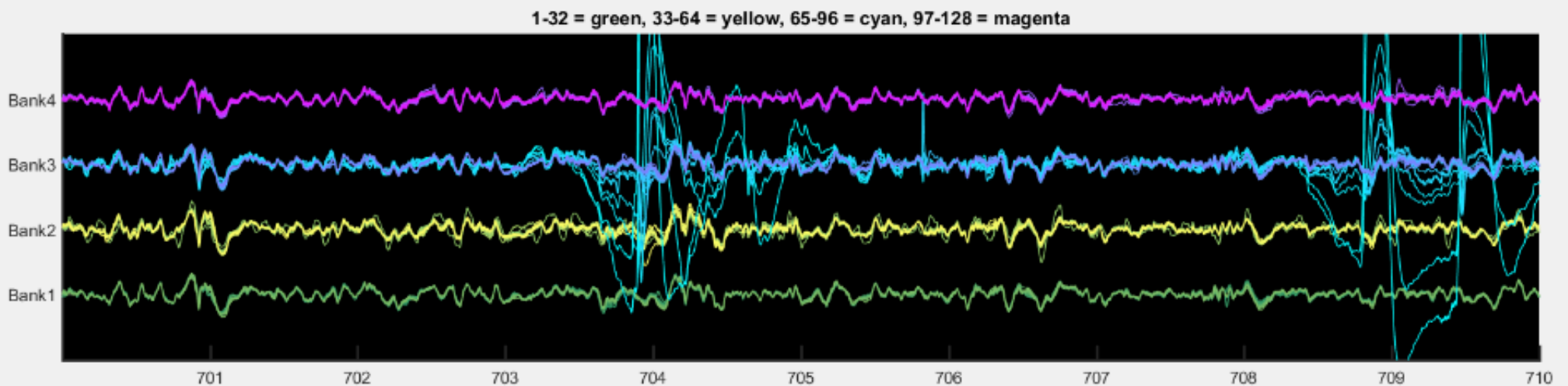
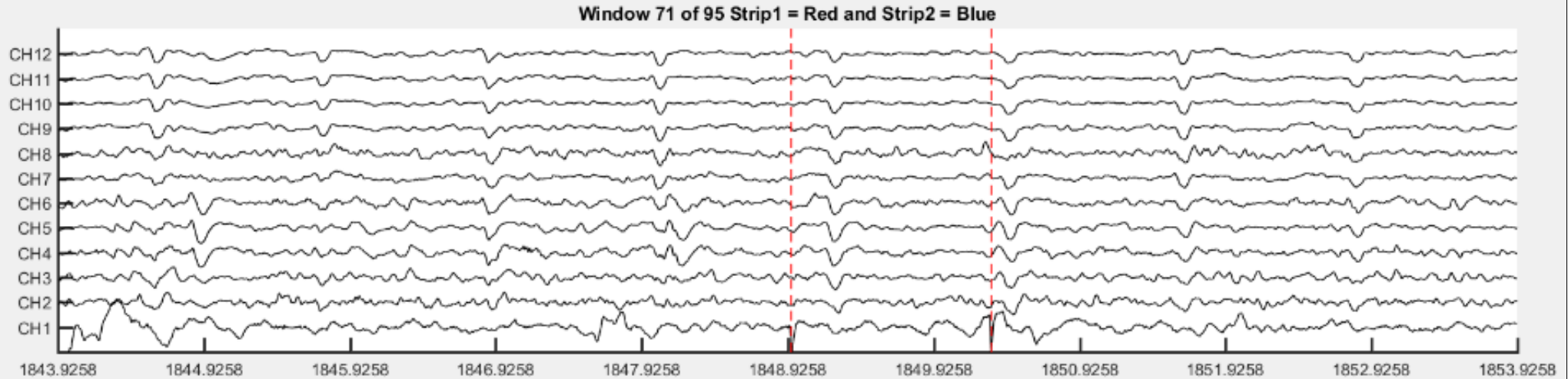


Activity in space



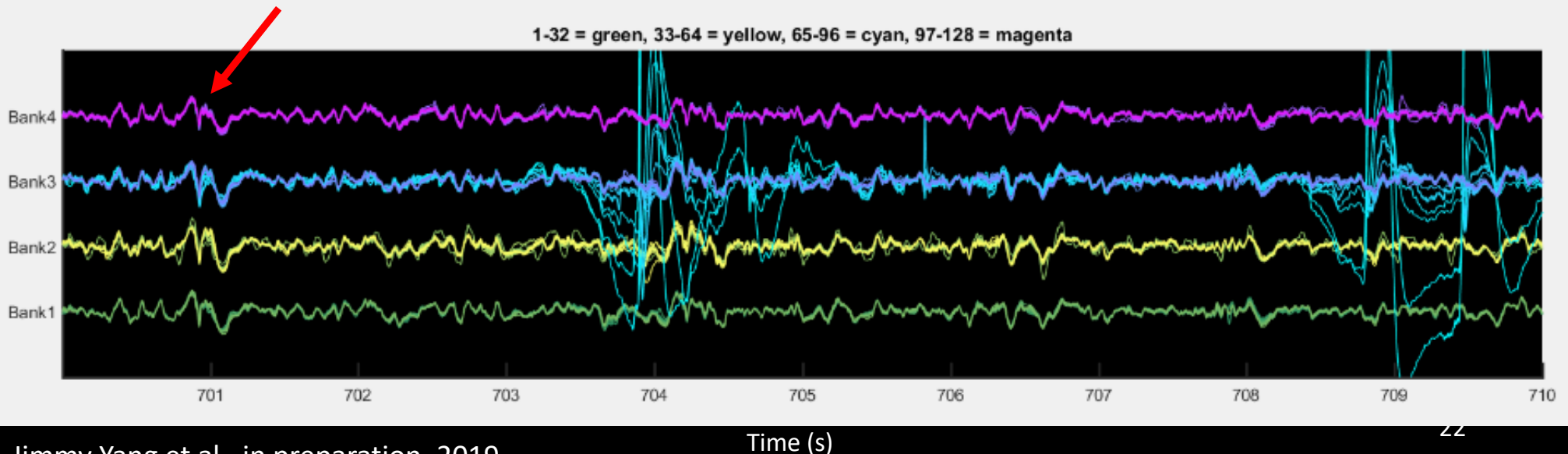
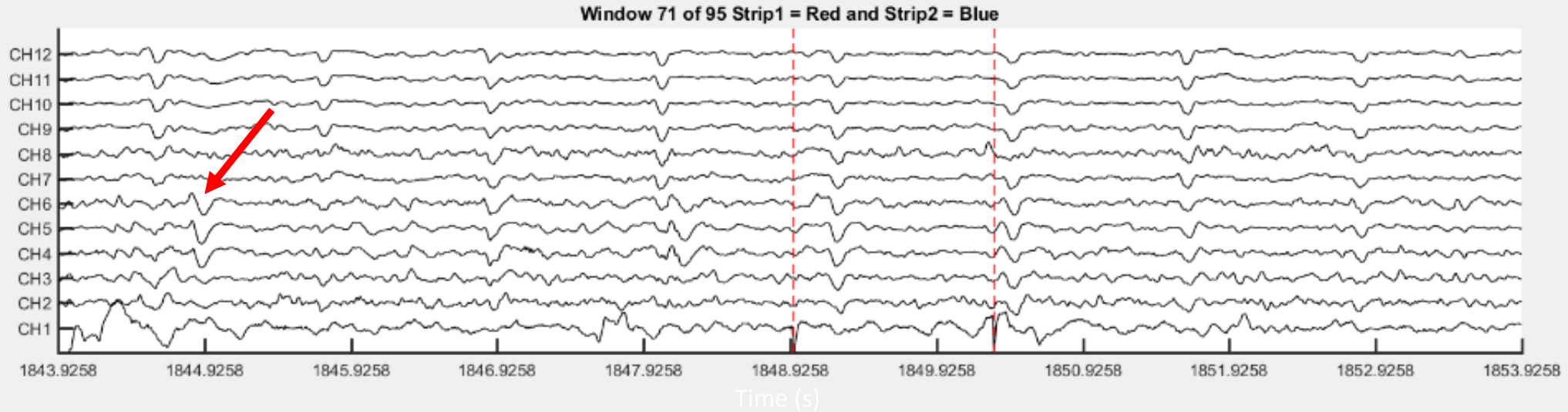
# Interictal Discharges (IID) in Epilepsy Patients: Spontaneous IID Traveling Waves

IIDs seen on both recording systems



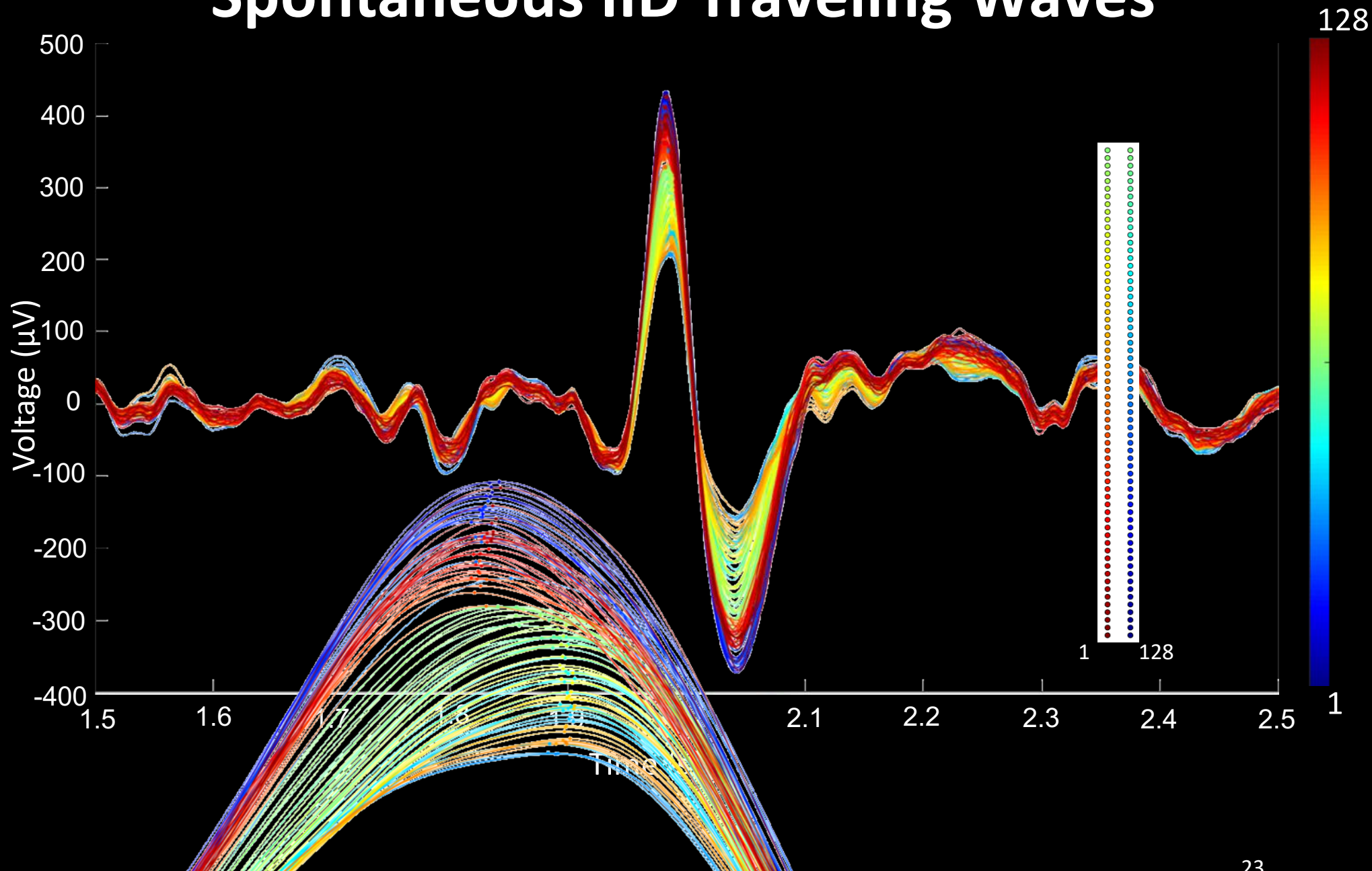
# Events seen similarly by each recording system – Interictal Discharges (IIDs)

IIDs seen on both recording systems





# Interictal Discharges (IID) in Epilepsy Patients: Spontaneous IID Traveling Waves





Jacobs Hall

# Intraoperative Recording at UCSD/MGH

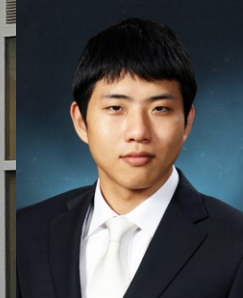
Dr. Ahmed Raslan, OHSU



Jihwan Lee



Youngbin Tchoe



Andrew Bourhis



Jeff Gertsch  
Neurology, UCSD  
Chief Neurophysiologist  
& experiment design



Sharona Ben-Haim  
Neurosurgery, UCSD  
Epilepsy and Pain  
management &  
experiment design



Joseph Ciacci  
Neurosurgery, UCSD  
Neurooncology &  
experiment design



Joel Martin  
Neurosurgery MD  
ECE PhD in progress  
Implant/experiment  
design





# Acknowledgment



NSF CAREER  
NSF SNM (CMMI)  
NSF ECCS/DMR  
(as of Sept. 2019)

Fabrication in SDNI, NSF-NNCI site @ UCSD



Center for Brain Activity Mapping



of the KAVLI Institute for Brain and Mind at UC San Diego



National Institutes  
of Health

This work was performed, in part, at the **Center for Integrated Nanotechnologies**, an Office of Science User Facility operated for the U.S. Department of Energy (DOE) Office of Science.



## Thanks to:

- **UC San Diego:**
  - Eric Halgren
  - Sharona Ben-Haim
  - Dan Cleary
  - Charles Dickey
  - Erik Kaestner
  - Vikash Gilja
  - Ian Galton
  - Vincent Leung
  - Joel Martin
  - The fantastic and patient OR staff
  - Timothy Gentner
  - Nasim Vahidi
  - Ezequiel Arneodo
  - **IEBL Lab Members at UCSD:**
  - Mehran Ganji
  - Lorraine Hossain
  - Hongseok Oh
  - Yun Goo Ro
  - Sang Heon Lee
  - Samantha Russman
  - Andrew Bourhis
  - Ritwik Vatsyayan
  - Youngbin Tchoe
  - Jihwan Lee
  - Ren Liu
- brain
- spine
- 1024 arrays
- nanowire

## Massachusetts General Hospital:

- Sydney Cash
- Angelique Paulk
- Jimmy Yang
- Yangling Chou
- Dan Soper
- Ziv Williams
- Daniel Cahill
- Brian Nahed
- Pamela Jones
- Douglas Maus
- Mirela Simon
- Aaron Tripp and the IOM team
- Scot Mackeil
- Scott Farren
- The fantastic and patient OR staff

## Brigham and Women's Hospital

- Garth Rees Cosgrove
- Jung Woo Lee
- Melissa Murphy
- Li Chen
- Susan Lovell
- The fantastic and patient OR staff