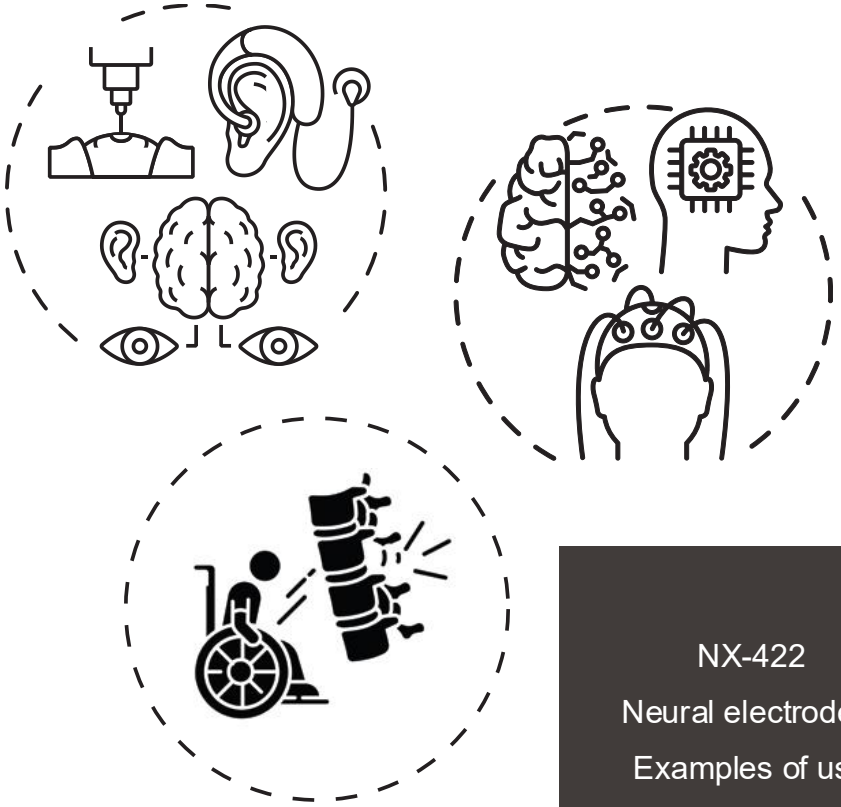


Neural Interfaces

NX-422

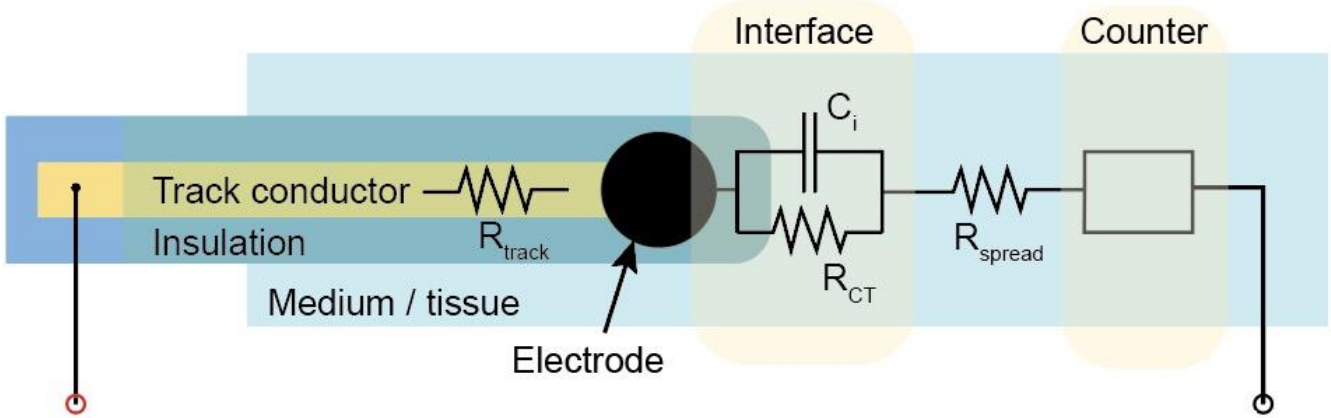
Neural electrodes:

Examples of use

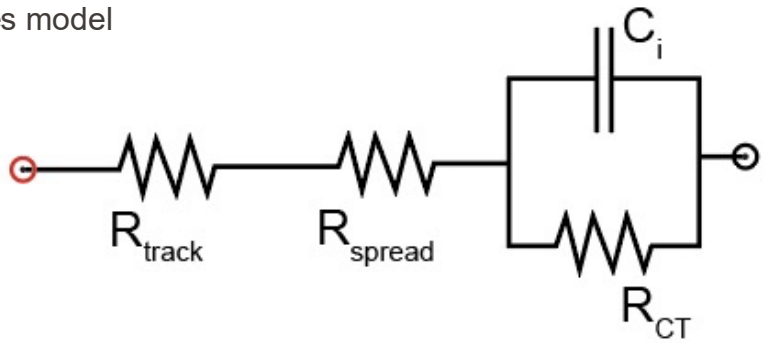
Giuseppe Schiavone

Neuro-X Institute

Equivalent electrical model of an electrode

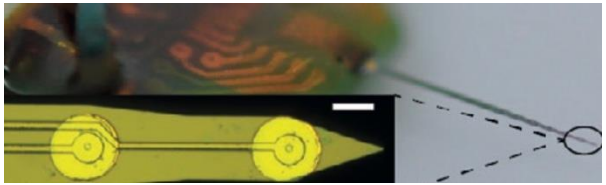


Randles model



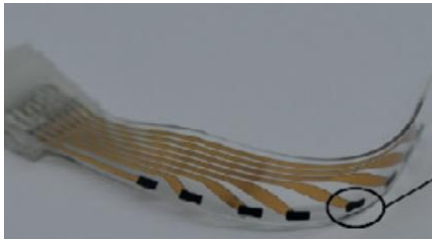
G. Schiavone et al, Neuron 2020

Analyse the Z(f) spectra



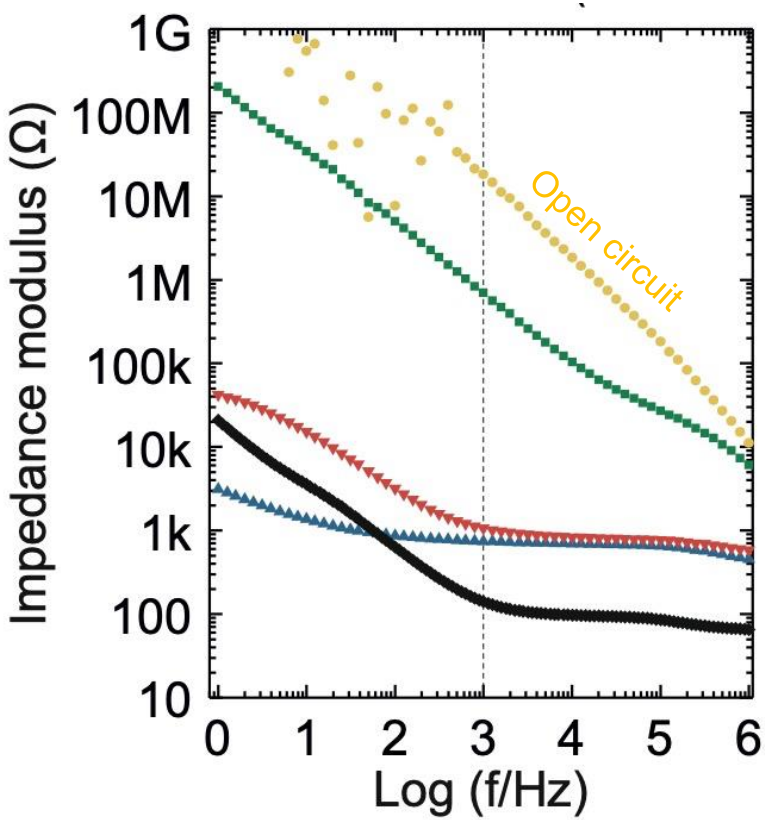
50µm ⌀
Thin-film

150µm ⌀
Thin-film



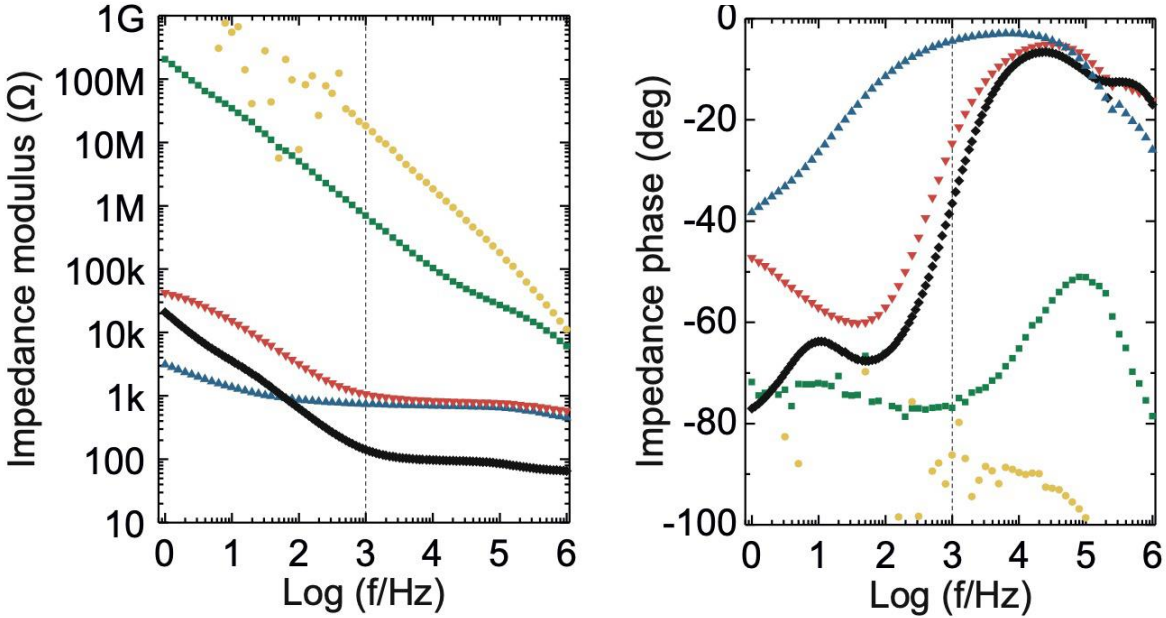
~ mm side electrodes
Thin-film

Medtronic 5-6-5 spinal cord stimulation paddle ~ 0.06 cm^2 GSA



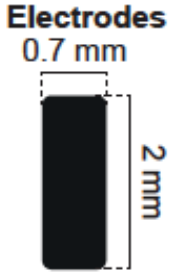
Can you match these Z plots?

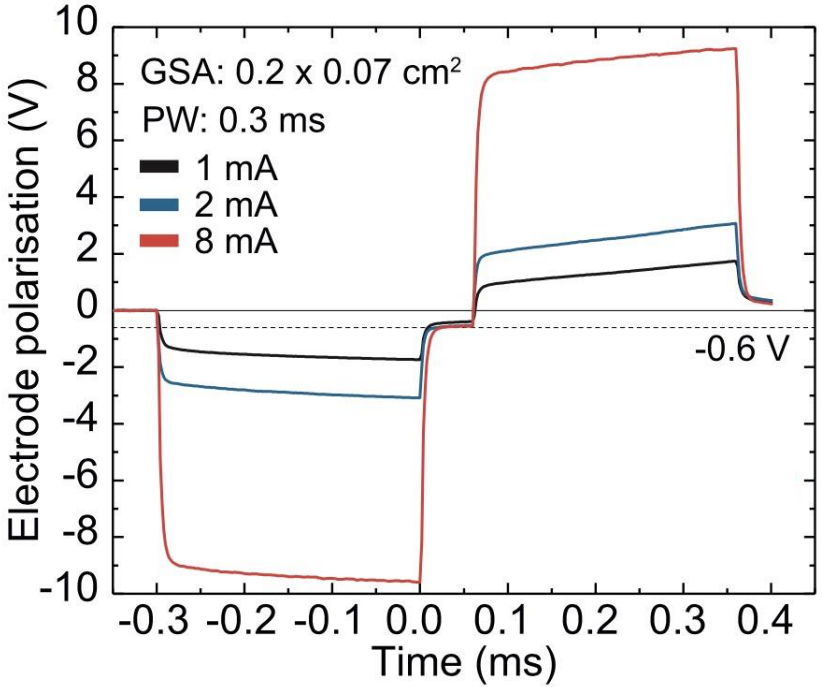
Solutions



Describe the phase behaviour

CIC_L – Charge injection capacity limit





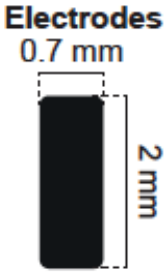
Calculate the CIC_L

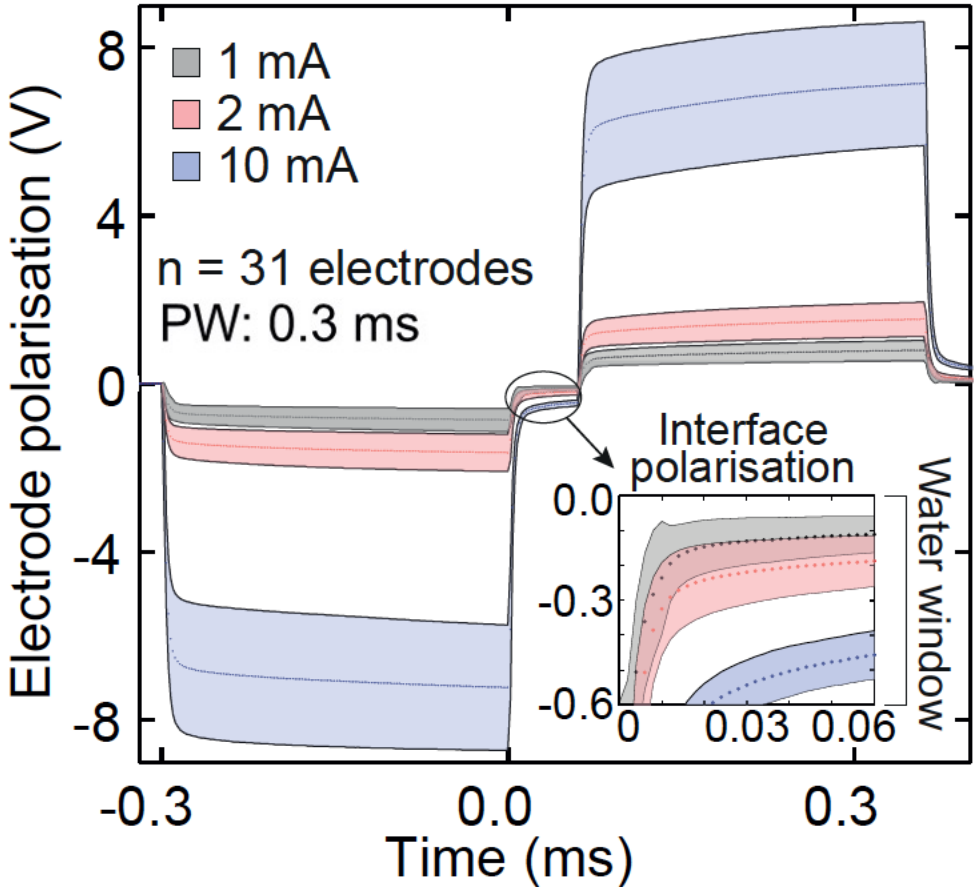
The electrode has a GSA of 0.2 x 0.07 cm^2

The biphasic current stimulation has a pulse width PW of 0.3ms.

The current is increased until the water window is reached.

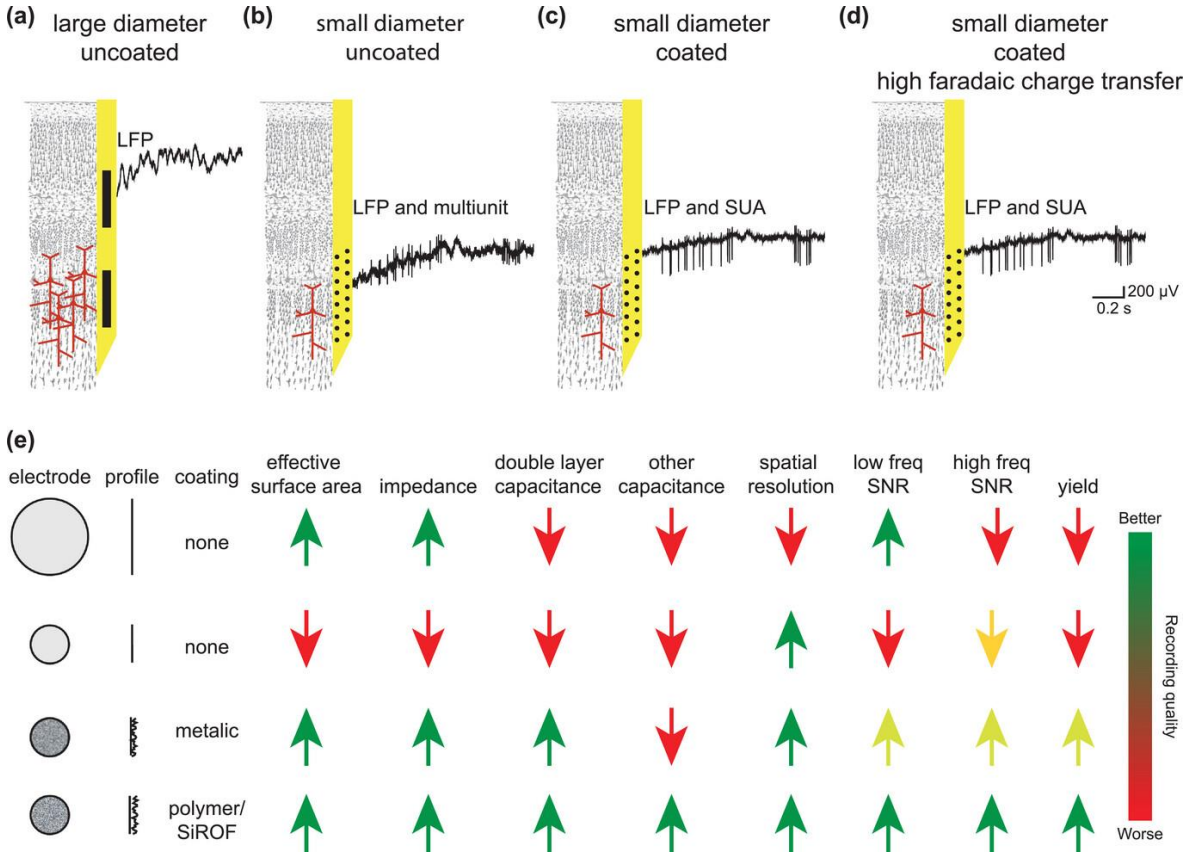
CIC_L – Charge injection capacity limit





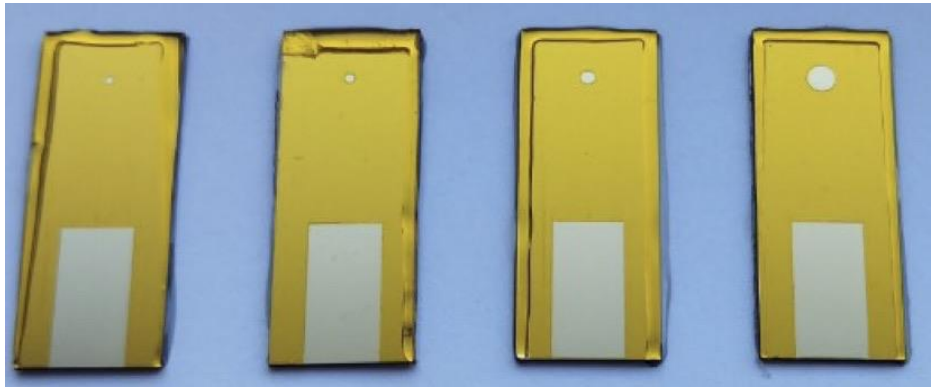
Calculate the CIC_L ?

Recording Quality Is Related to Impedance



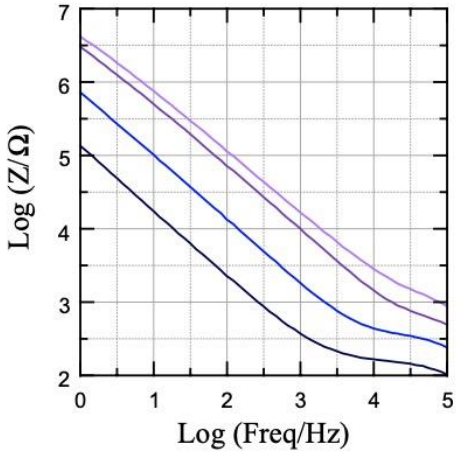
Lewis 2024

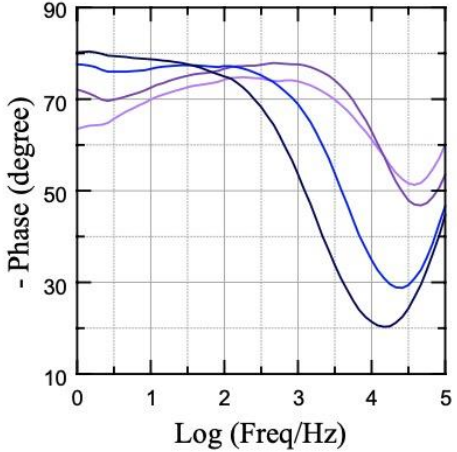
Reducing the impedance of Au electrodes



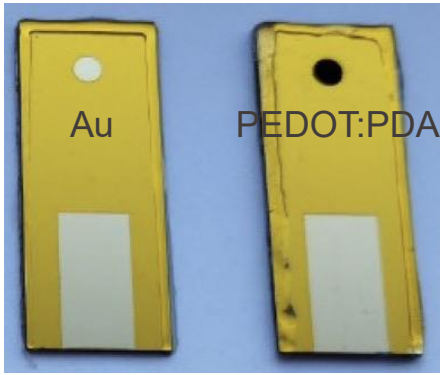
Saghir et al. 2025

What equivalent circuit model can you use to fit the EIS data?





Reducing the impedance with PEDOT:Polydopamine

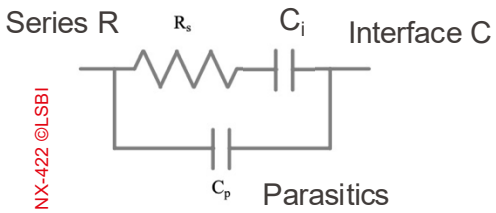


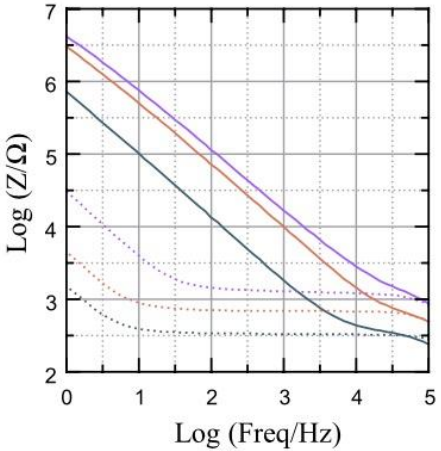
Gold electrodes: Solid lines

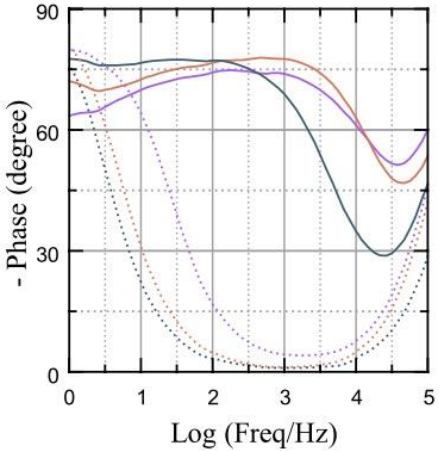
1mm 500µm 300µm

Coated electrodes Dashed lines

1mm 500µm 300µm

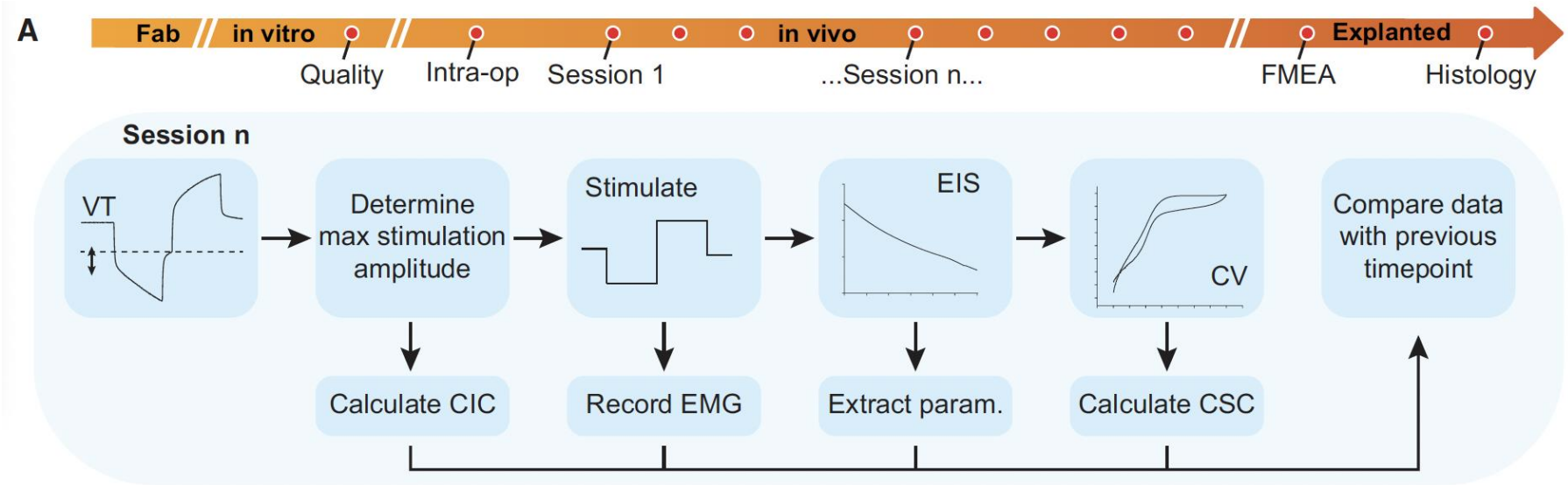






What parameter is improved by the coating?

Series of electrode characterisation: from fab to in vivo

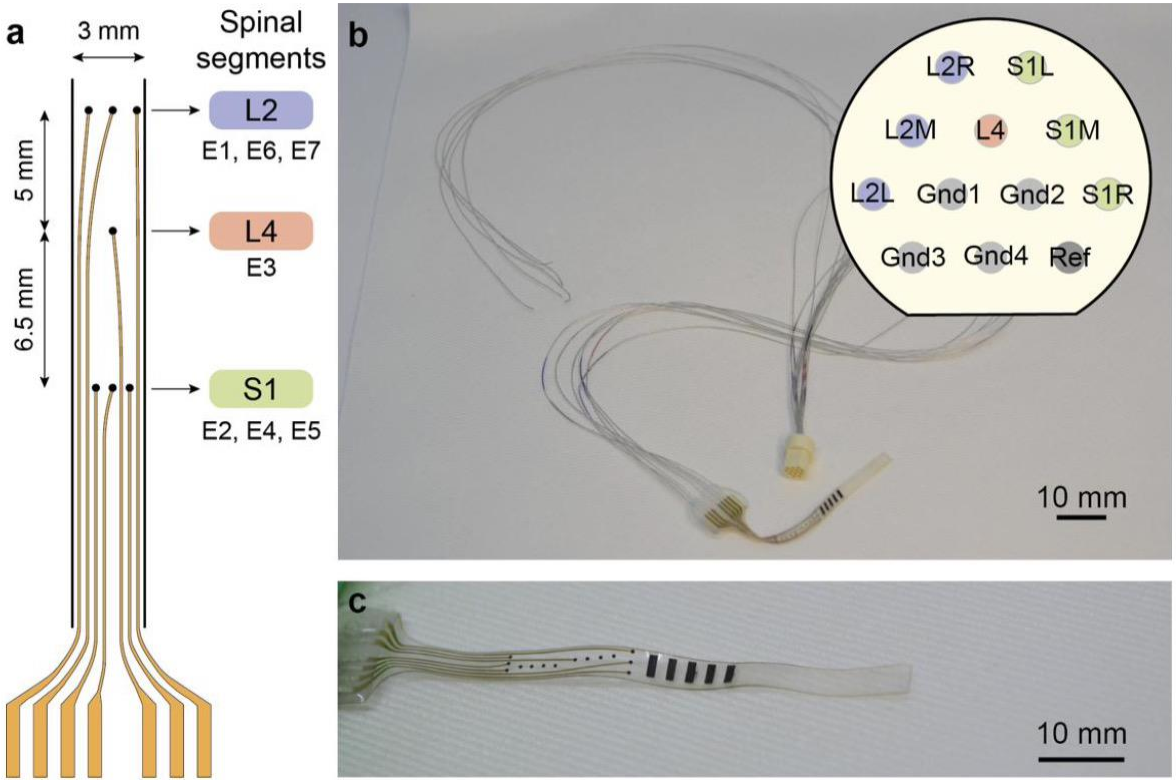


G. Schiavone et al. Neuron (2020) 108, pp. 238-258

Series of electrode characterisation: from fab to in vivo

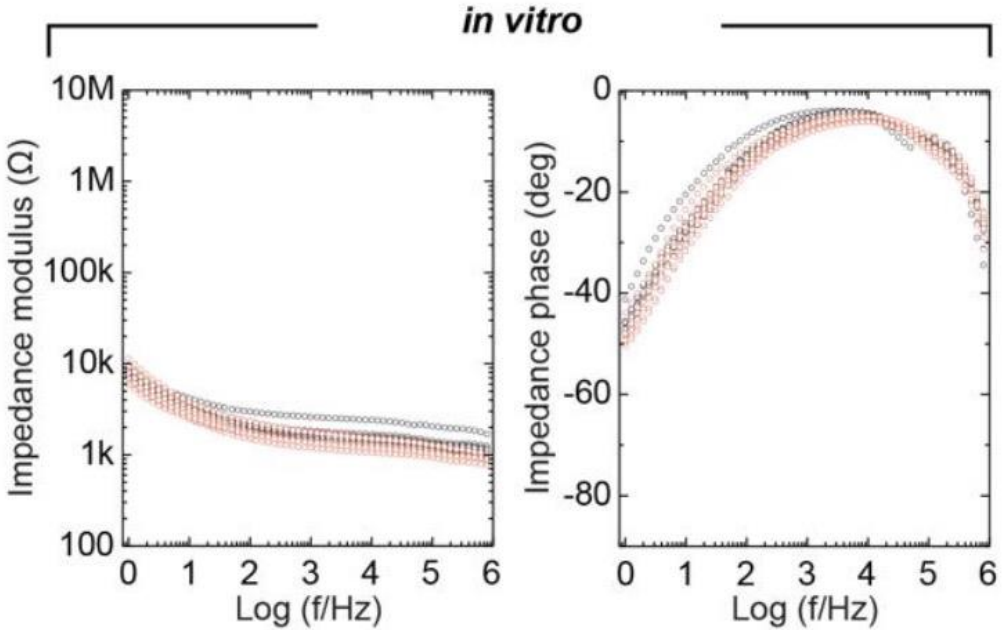
Rat section

5 mm



G. Schiavone et al. Neuron (2020) 108, pp. 238-258

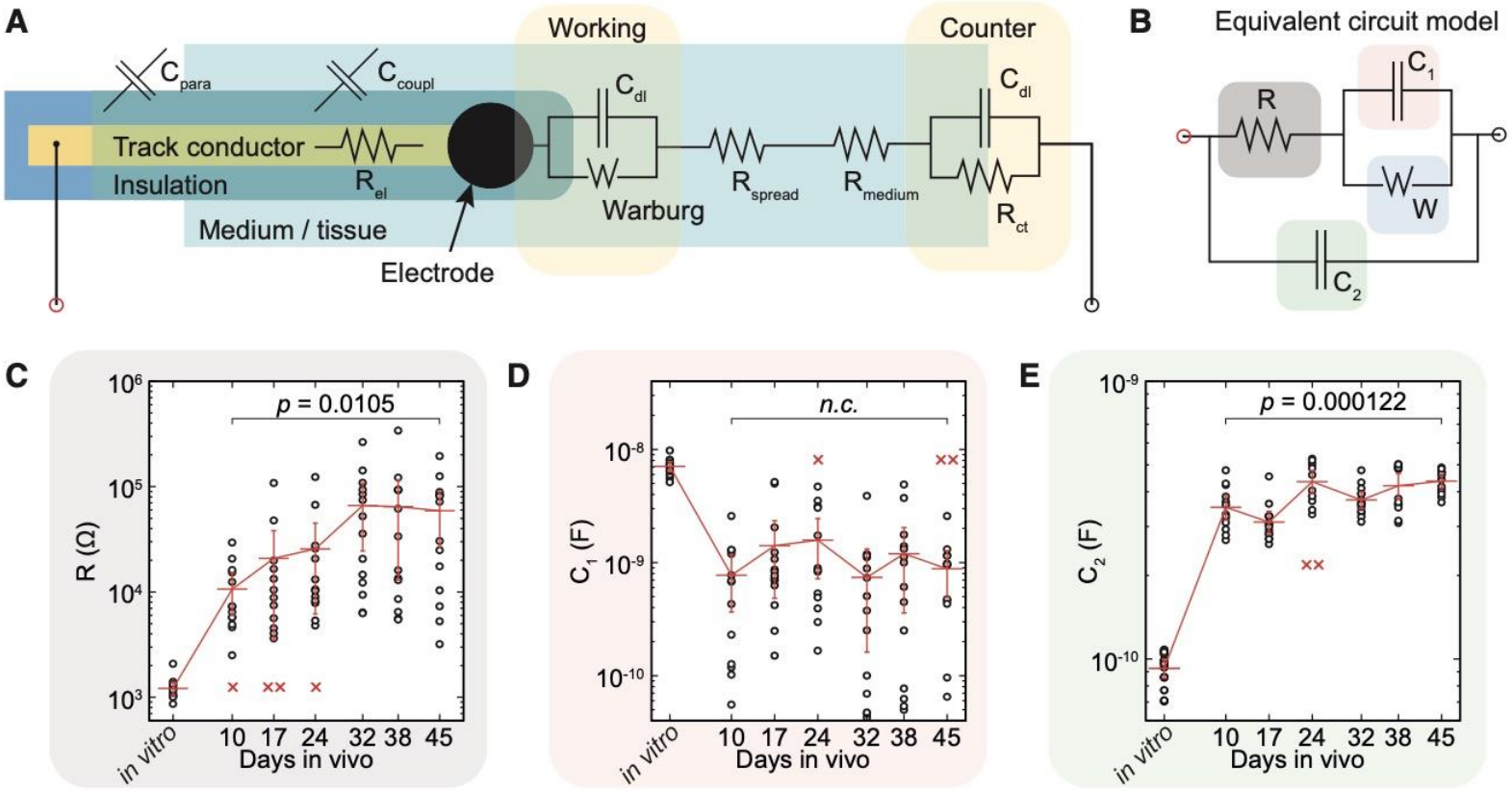
Series of electrode characterisation: from fab to in vivo



What characteristics can you highlight from the EIS spectrum?

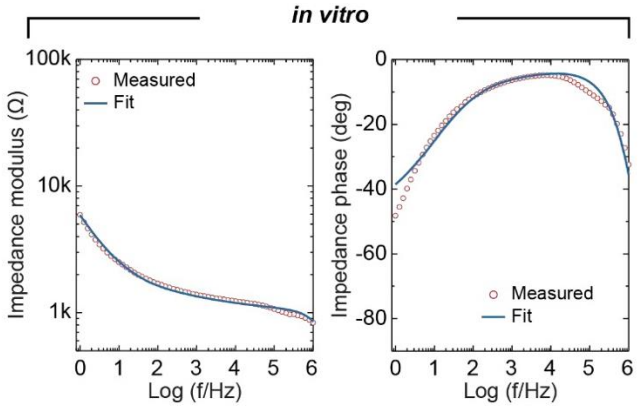
G. Schiavone et al. Neuron (2020) 108, pp. 238-258

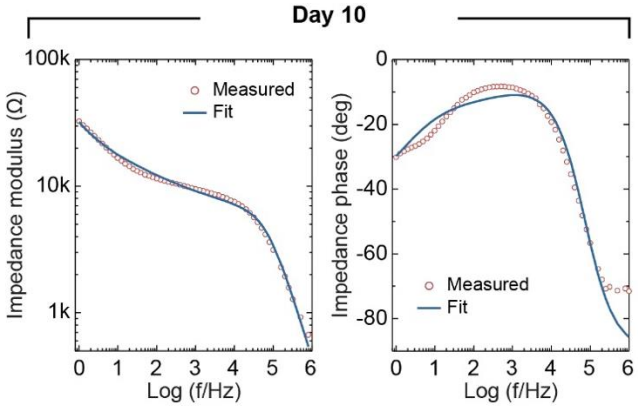
Series of electrode characterisation: from fab to in vivo – real example

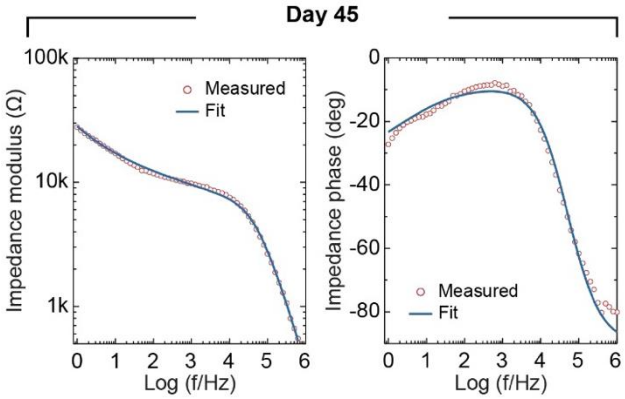


G. Schiavone et al. Neuron (2020) 108, pp. 238-258

Series of electrode characterisation: from fab to in vivo







What changes can you identify?

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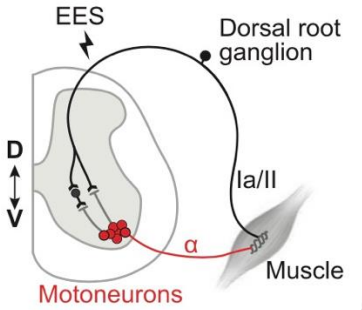
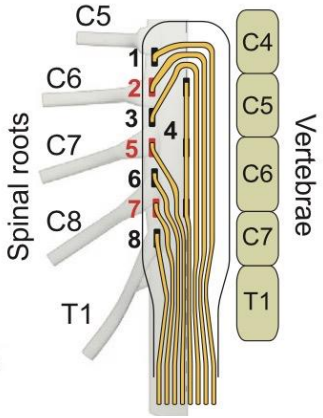
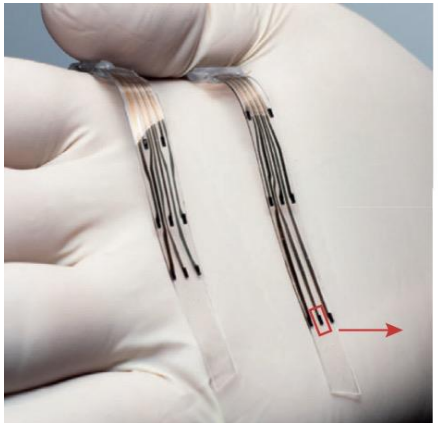
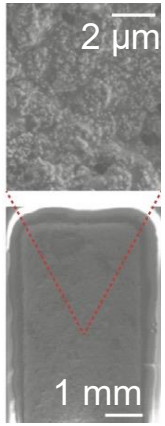
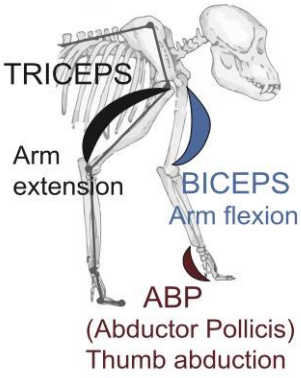
Spinal cord stimulation for motor neuroprosthetics

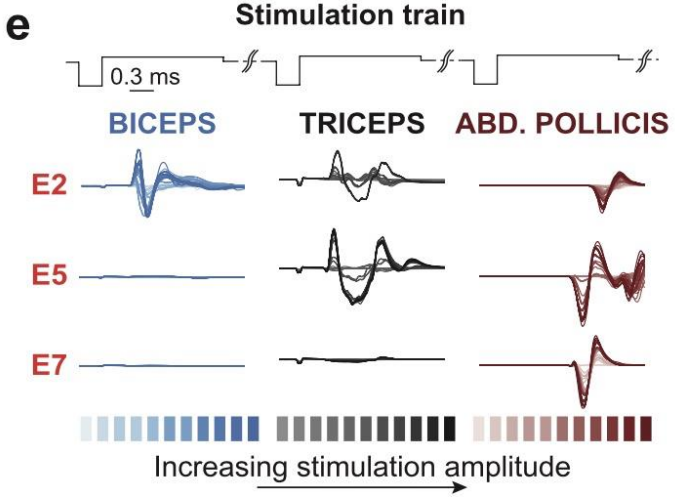


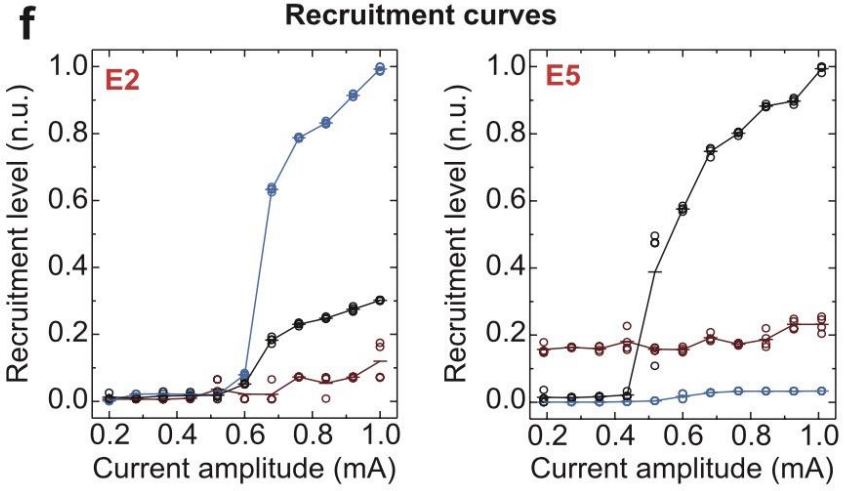






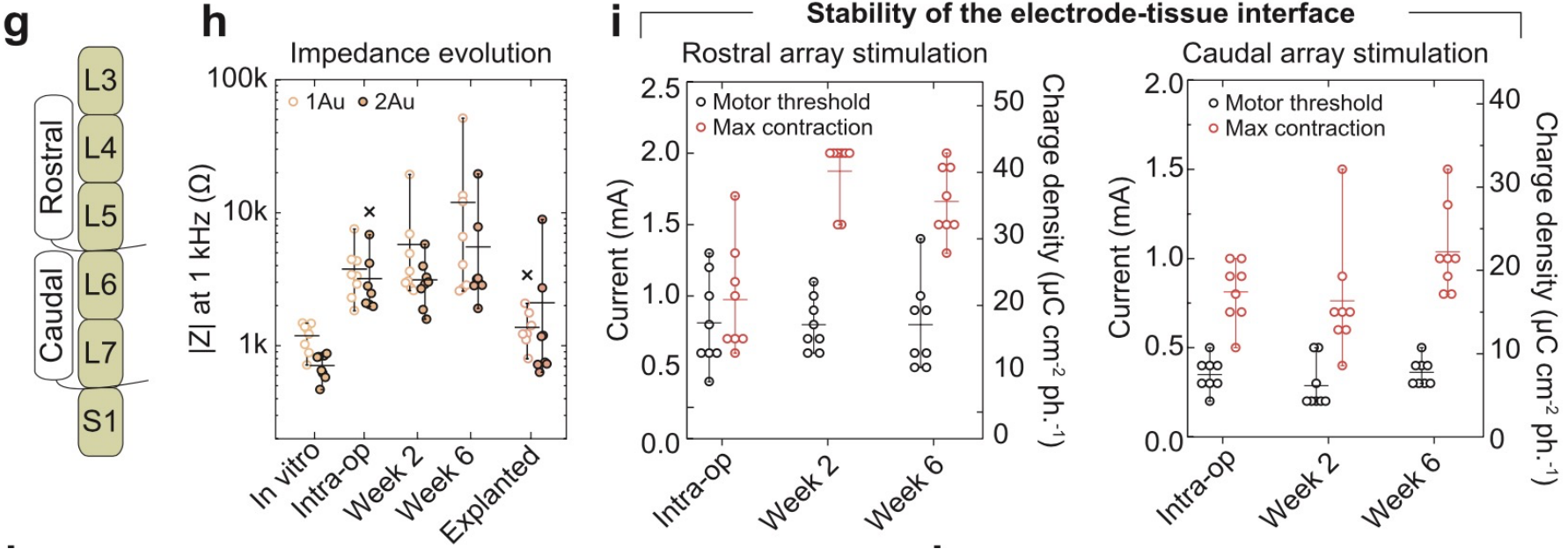






G. Schiavone et al. Adv. Mater. 2020

Spinal cord stimulation for motor neuroprosthetics



G. Schiavone et al. Adv. Mater. 2020

Spinal cord stimulation for motor neuroprosthetics

Example of experimental protocol:

1. Design electrodes (and electrode system) according to biological input:
   - → Which structures you want to interface with
   - → What materials can you use (trade-off mechanics vs. electrical/insulation performance)

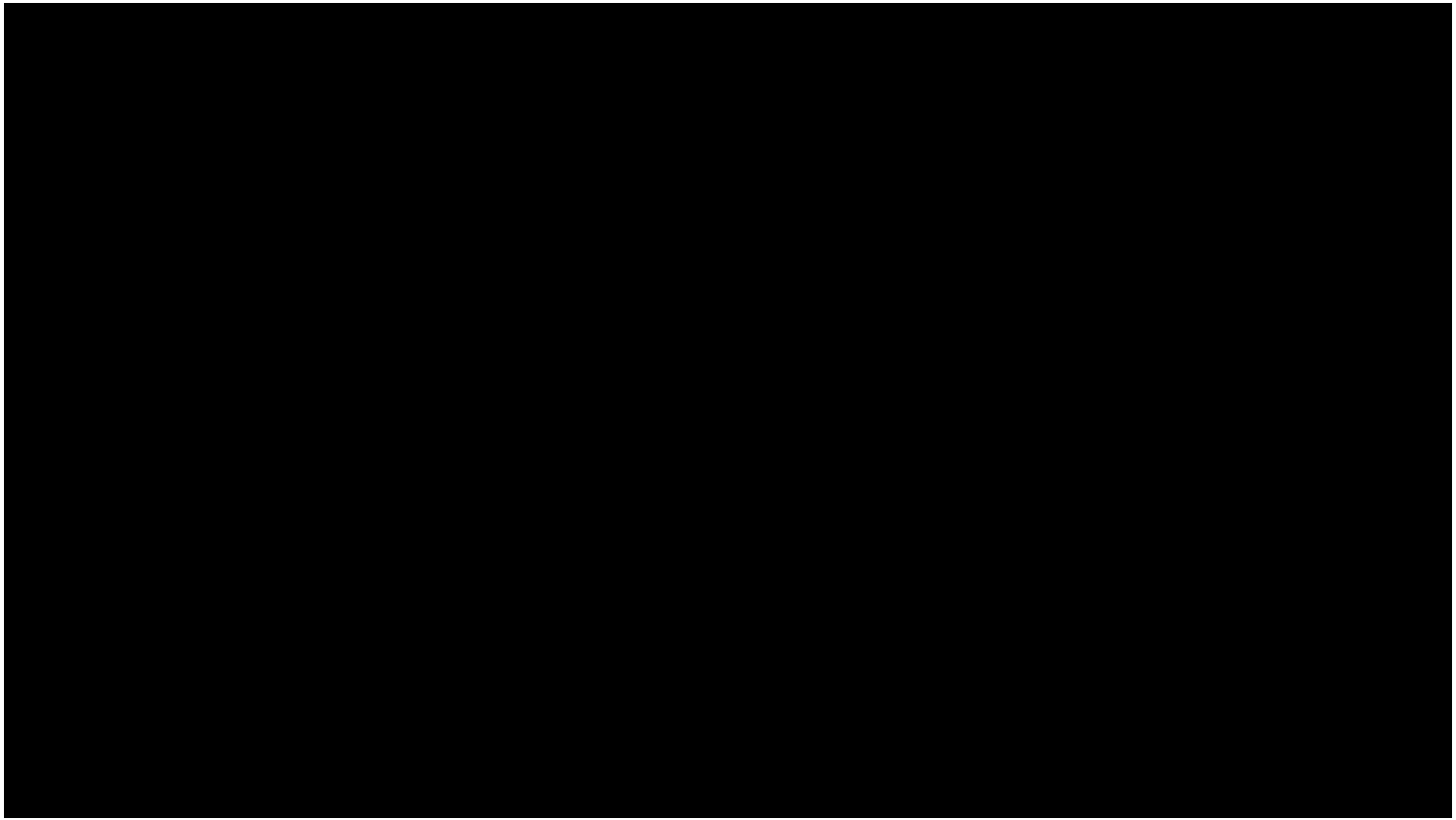
2. Verify function of the interface:
   - → Is stimulation effective? (i.e. is the effect what you want/expect)
   - → Are functional thresholds within safe limits? (i.e. Shannon and water-window)

3. Characterise the electrodes:
   - → VT, EIS, CV
   - → Look at EIS spectrum, decide an equivalent circuit model and extract fitting parameters

4. Evaluate stability over time:
   - → Repeat characterisation and data fitting
   - → Identify changes in the measurements and interpret / act

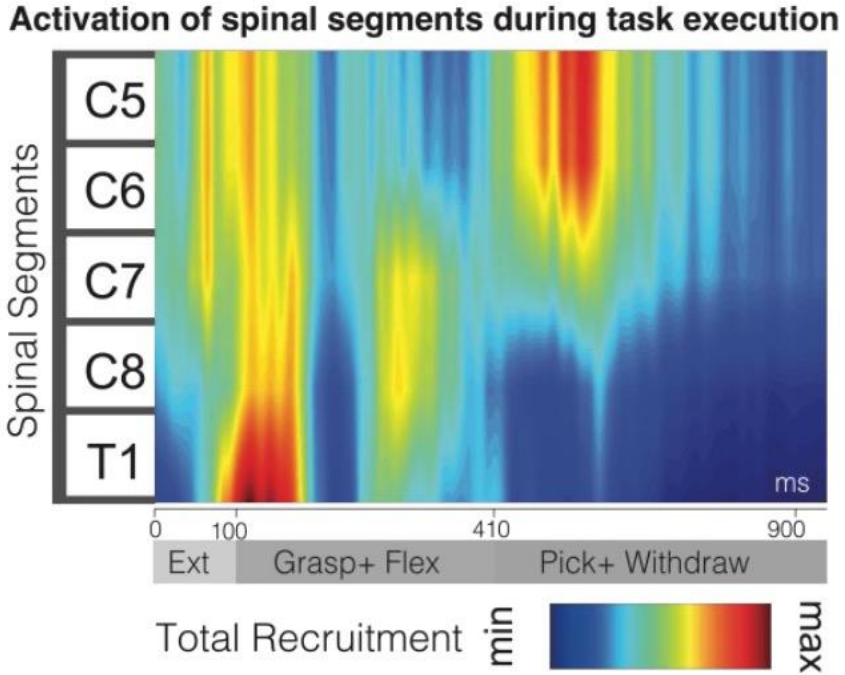
5. Explant and characterise:
   - → Observe surface residue, check integrity / functionality

Spinal cord stimulation for motor neuroprosthetics



Barra et al. IEEE EMBC. 2018

Spinal cord stimulation for motor neuroprosthetics



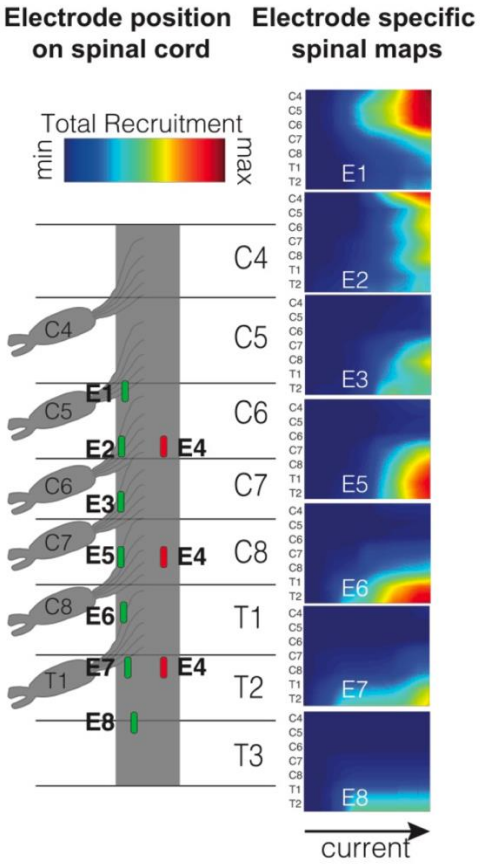
1. Muscle activity (8 muscles) extracted during task execution using independent EMG electrodes

2. EMG activity is back projected to spinal segment activity using innervation atlases

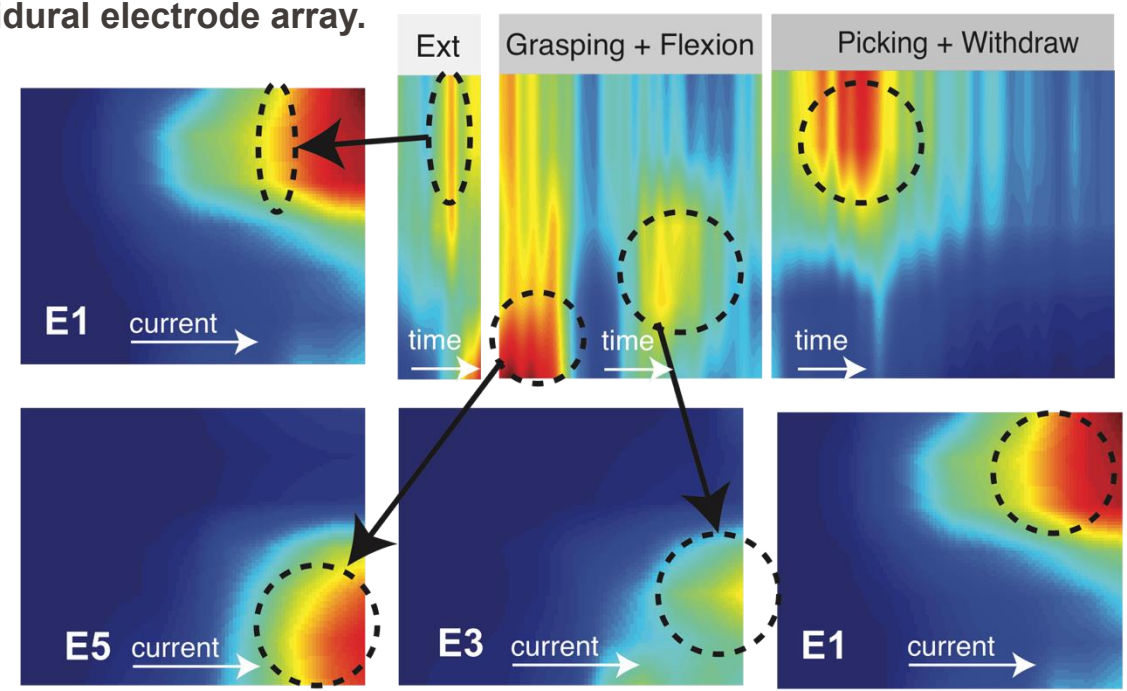
3. Identify activation pattern that we would like to reproduce artificially

Barra et al. IEEE EMBC. 2018

Spinal cord stimulation for motor neuroprosthetics



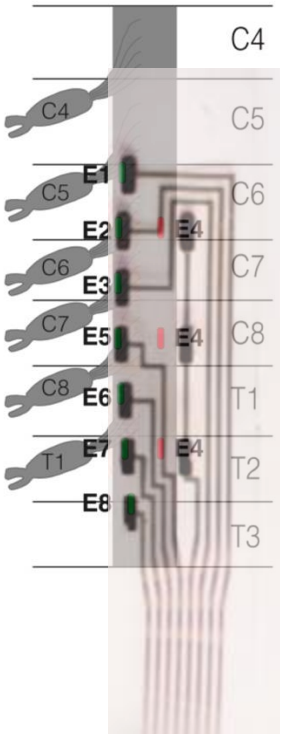
Mapping spinal activation in response to electrical stimulation with an epidural electrode array.

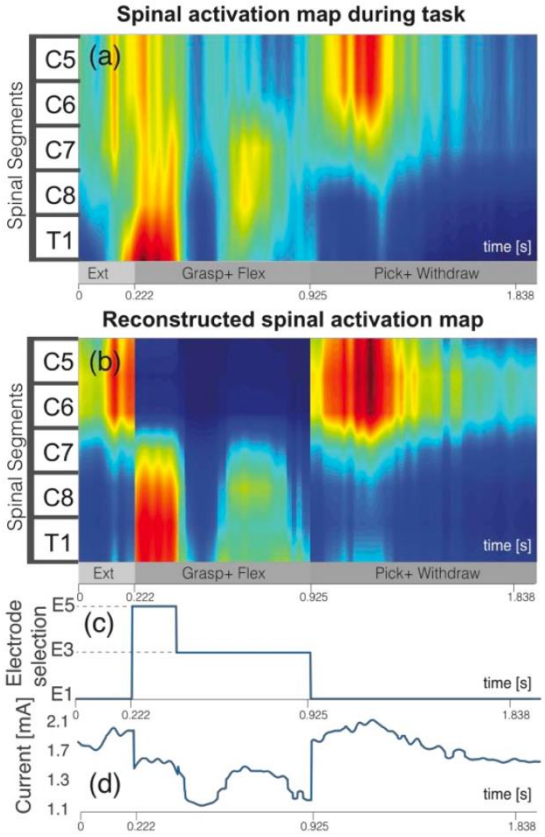


Identify electrodes and current amplitudes that can be used to reconstruct the natural activation pattern on the spinal cord

Barra et al. IEEE EMBC. 2018

Spinal cord stimulation for motor neuroprosthetics





Design of neurostimulation waveform

Barra et al. IEEE EMBC. 2018