Artist Design
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The Wetware-Hardware Interface:
Three ways of interfacing our brain to a computer

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Overview

Why interfacing computers to the brain?

System level interfaces

Macro level interfaces

Micro level interfaces

From Science Fiction to Science Fact?

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What 40 years "More Moore" brought to us…

From 200 bytes filling a big room…

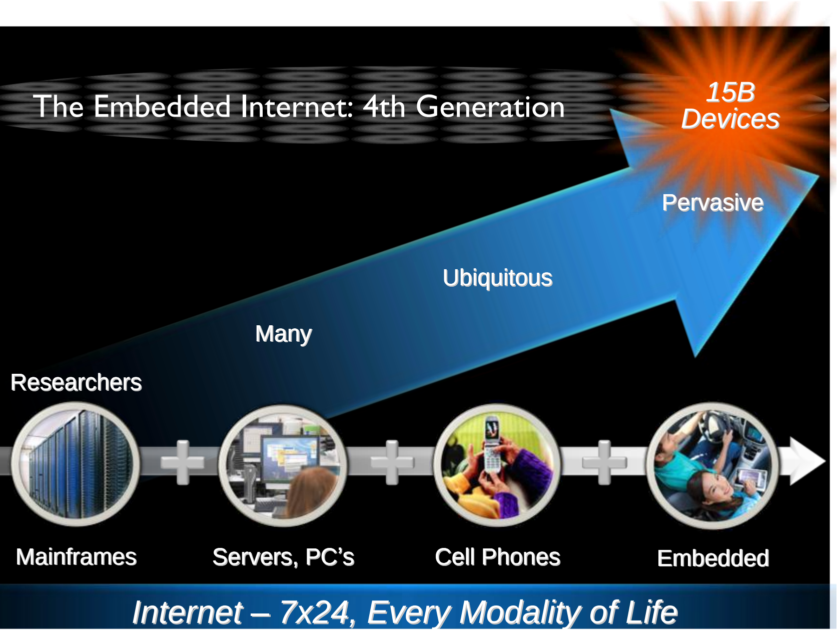
To 32 Gbytes filling your pocket…

Nevertheless, input/output remained the same…

Output: screen

Input: keyboard

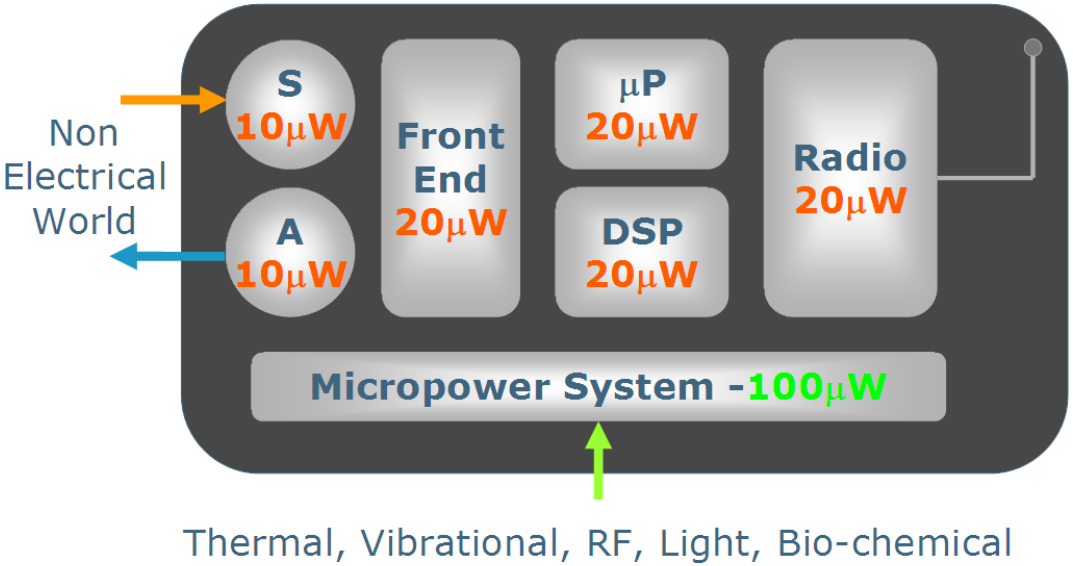
From a computer-in-your-pocket to hidden-electronics-everywhere: autonomous interfaces to the real-world needed



© Intel

Heterogeneous interfaces needed

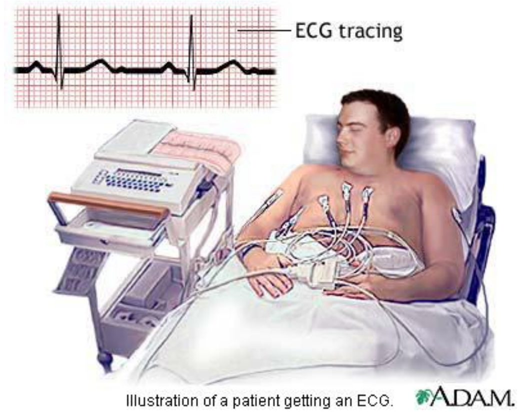
Revolution enabled by More than Moore

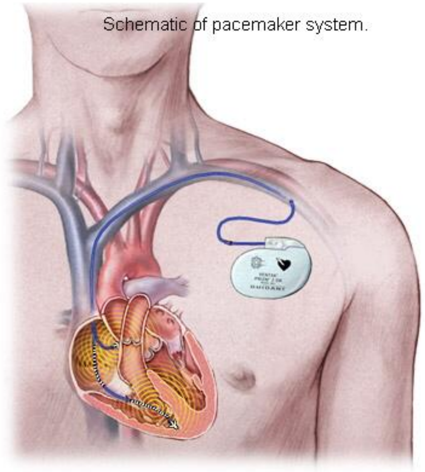


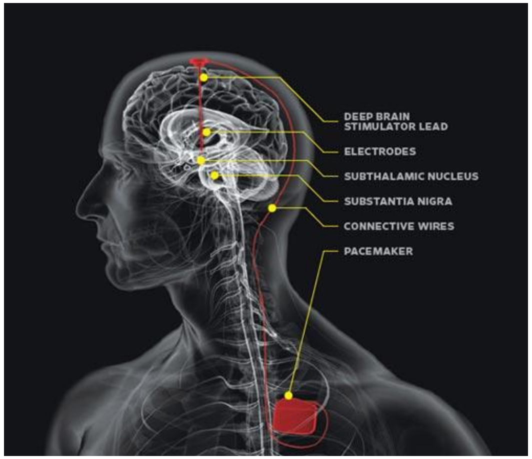
For health care related hidden-electronics-everywhere, we need interfacing with electrogenic characteristics of the body

System level –
electrical activity of all neurons measured outside the body

Too bulky
Too uncomfortable







Micro level –
electrical activity of one neuron measured/stimulated inside the body

Non existent

Macro level –
electrical activity of a region of neurons stimulated inside the body

Too coarse
No feedback loop

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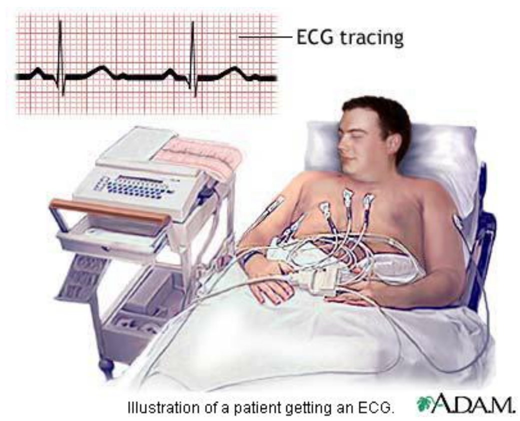
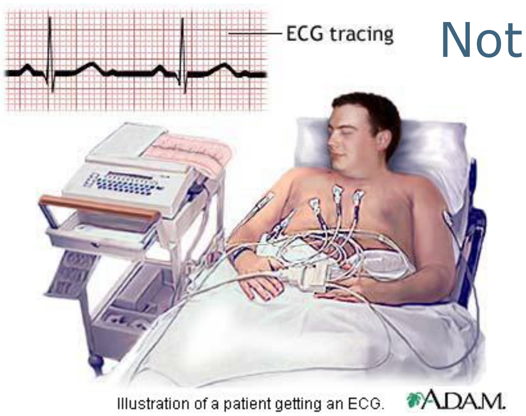
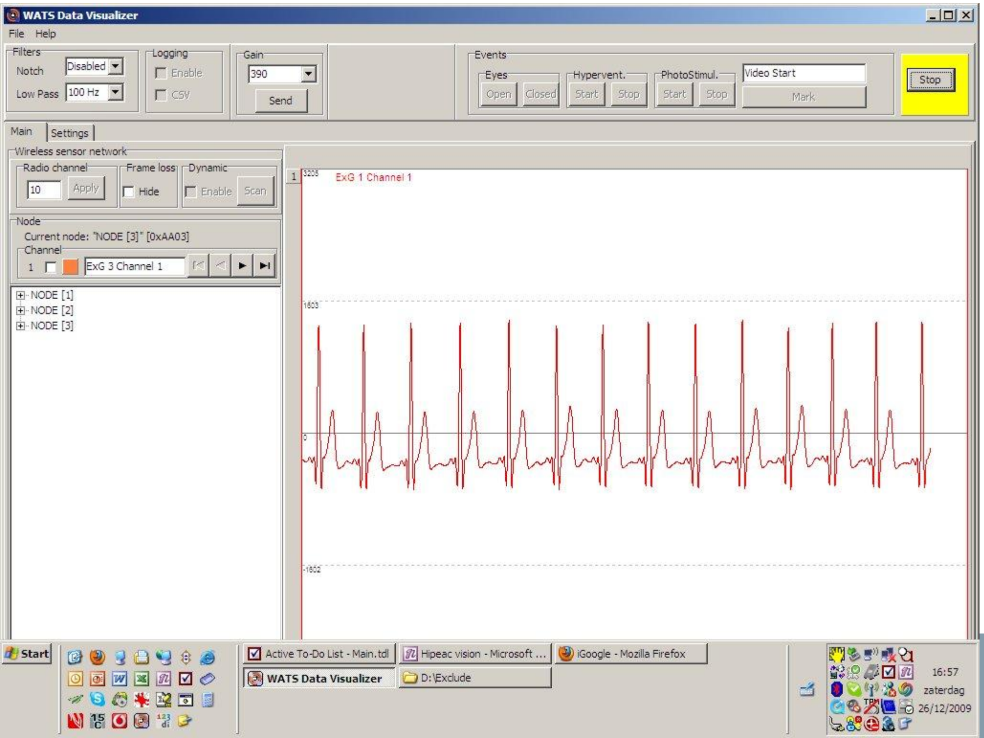
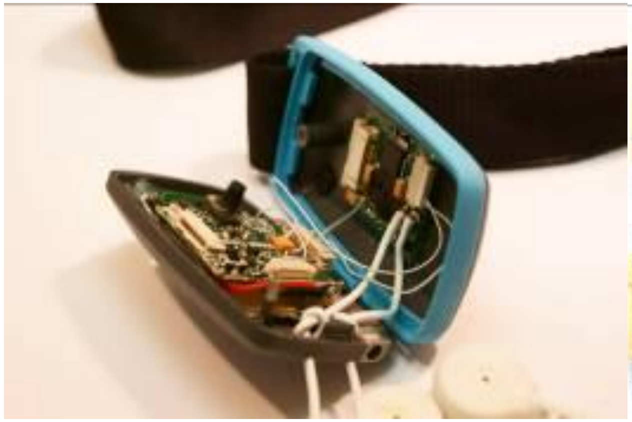


What miniaturization can bring you:
See your heart activity… comfortably and continuously



Not this… but this…

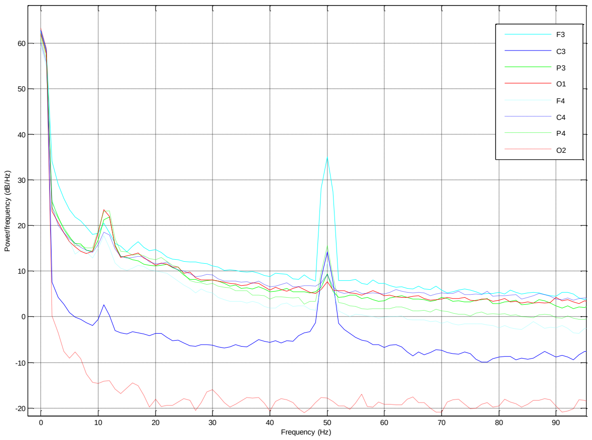




What miniaturization can bring you:
Hear your brain activity… comfortably and continuously

Not this…

but this…



Listen to your brain activity

What miniaturization can bring you: Hear your brain activity… comfortably and continuously

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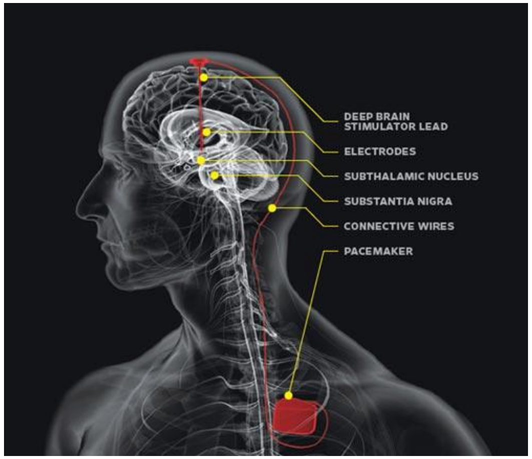
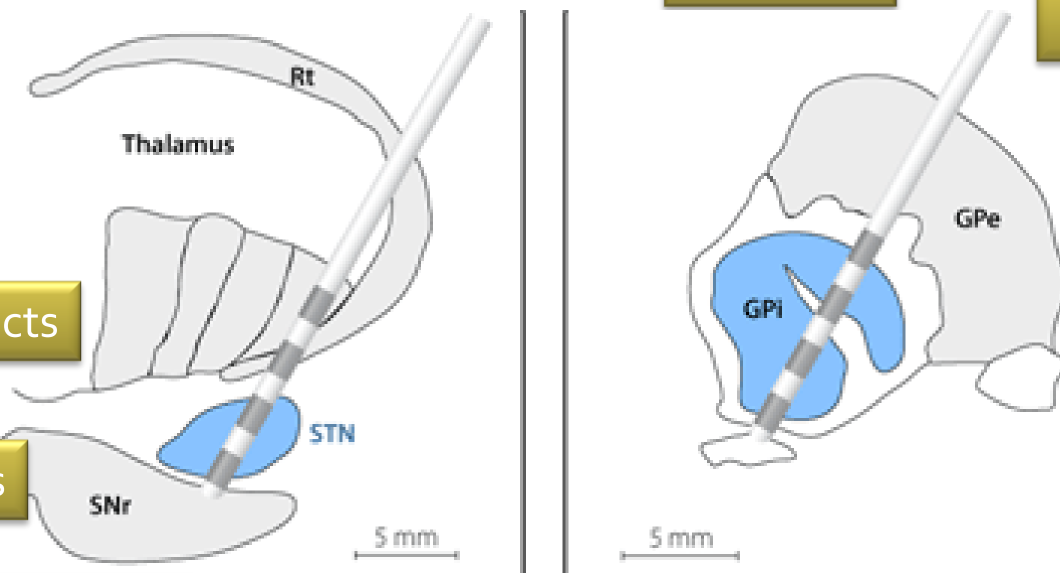


Challenges for DBS implantable devices

Electrode stability

MRI compliance

Easy handling



More contacts

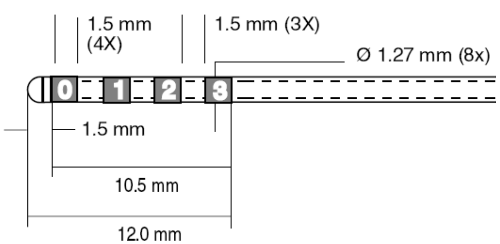
Smaller contacts

Stimulation & Recording

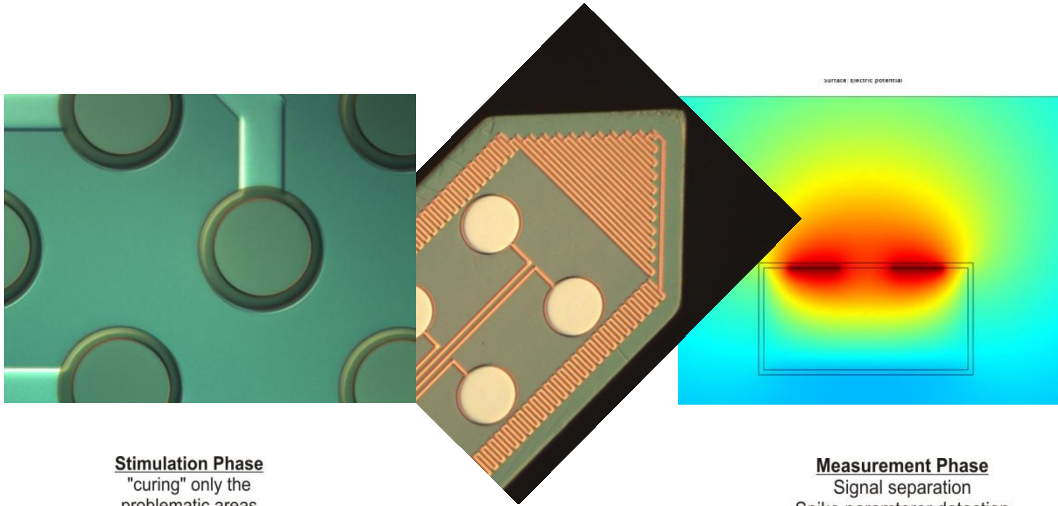
Steering & calibration

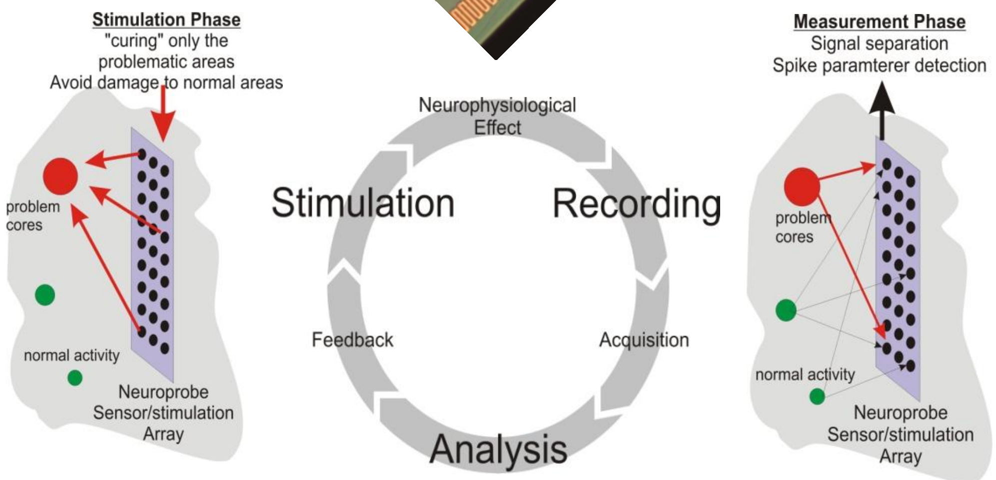
Test path
- Therapy finding
- Approval
- Human use

VISION: *in vivo*



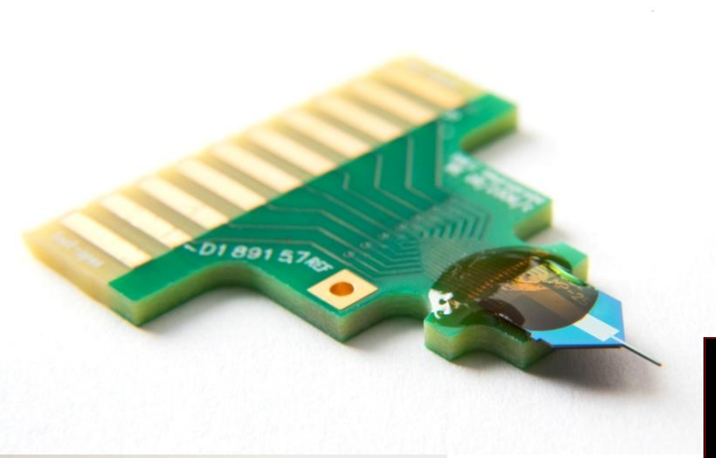
Medical DBS practice today

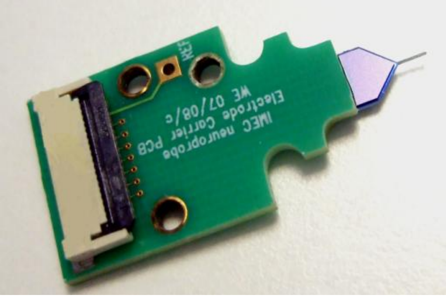


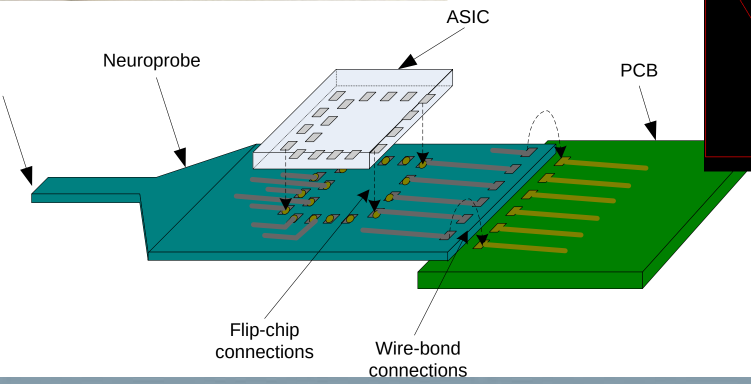


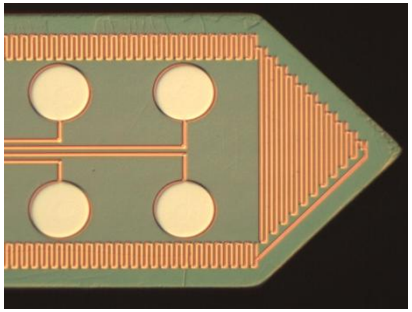
IMEC approach

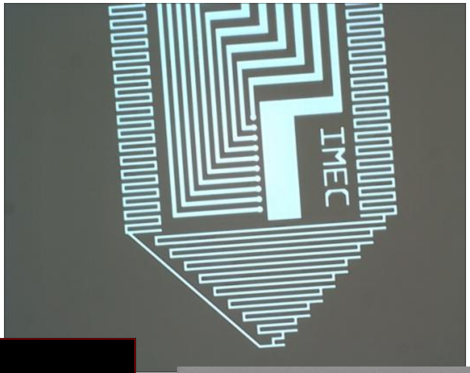
Wafer-level micro fabrication & packaging of neural probes

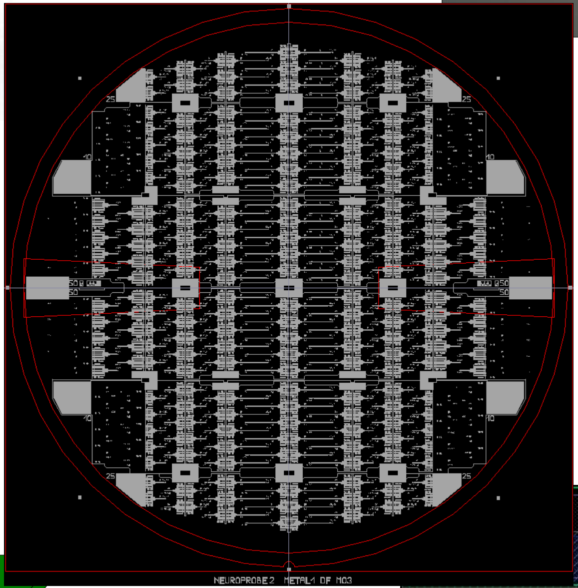


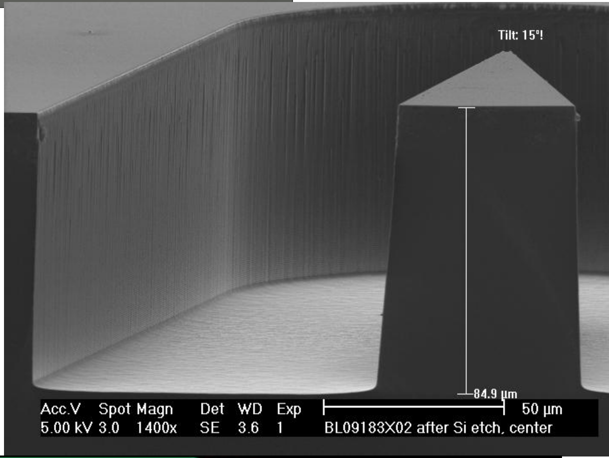


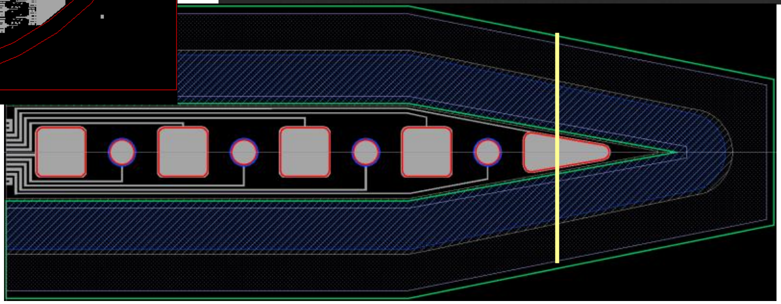




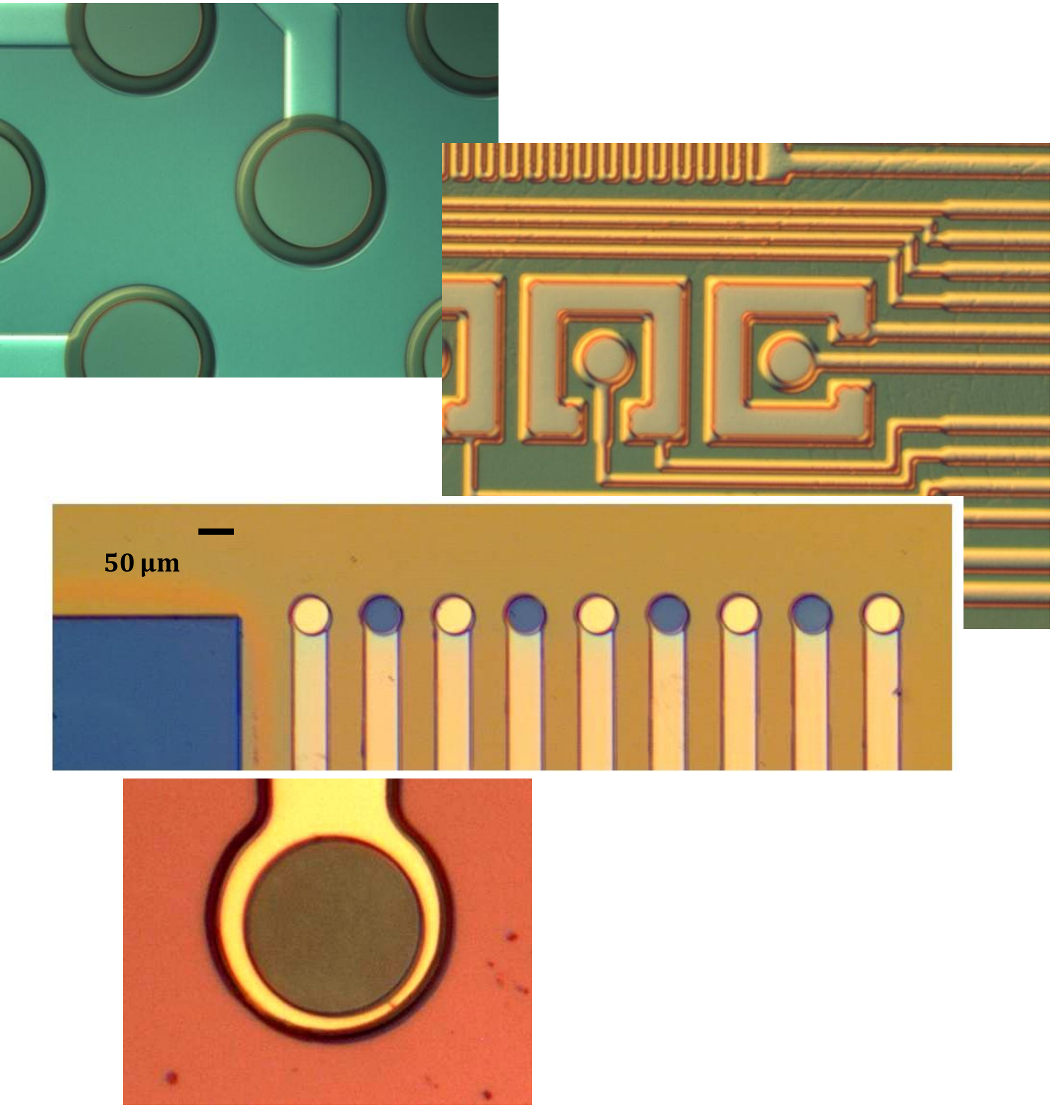


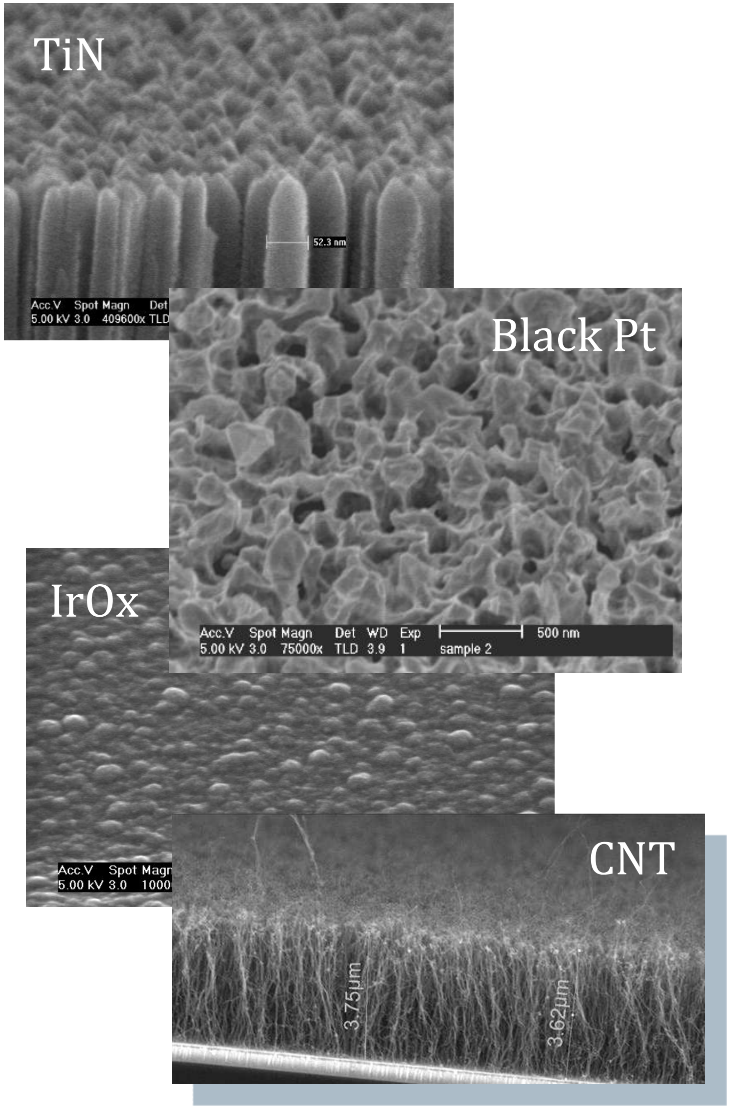




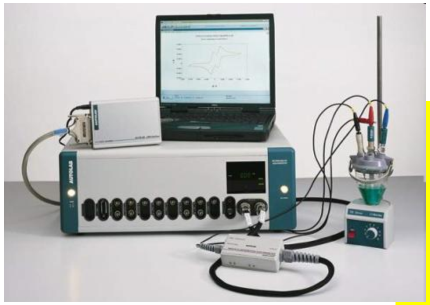


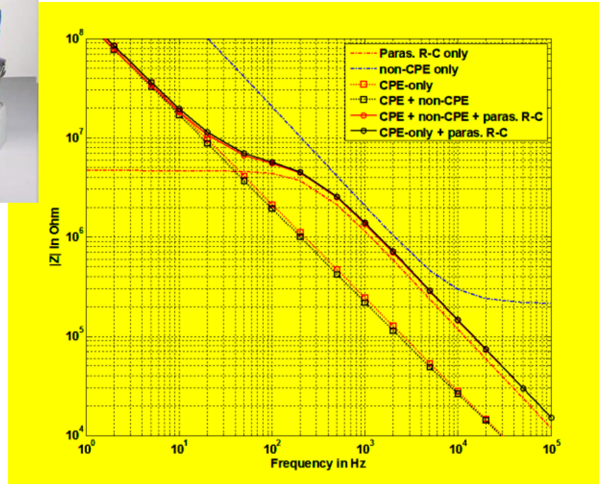
Broad choice of topologies & materials characterized in solution, in vitro, in vivo

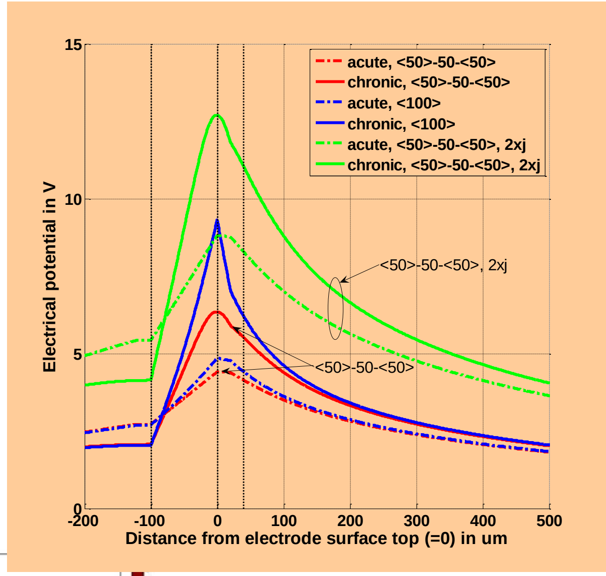


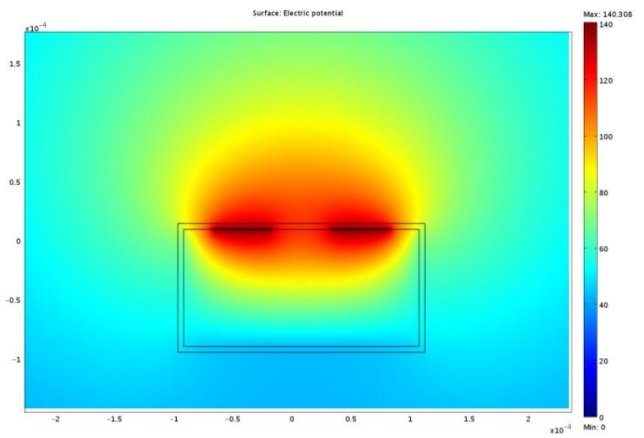


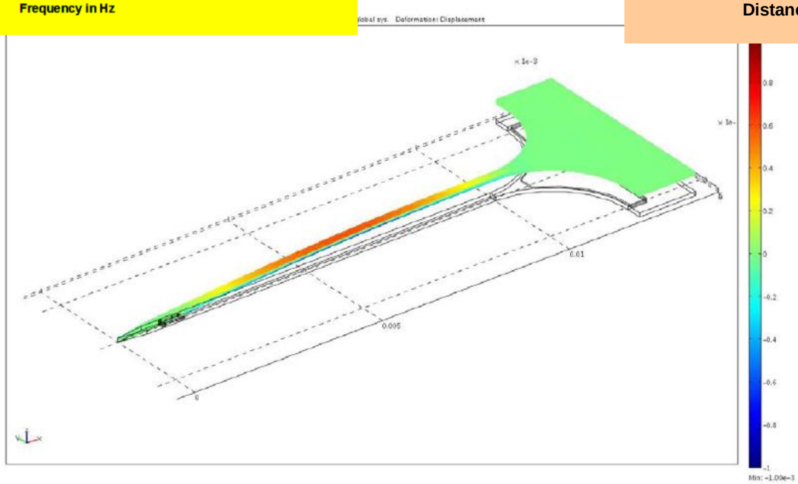
Efficient design cycle using experimental characterization – modeling – simulation



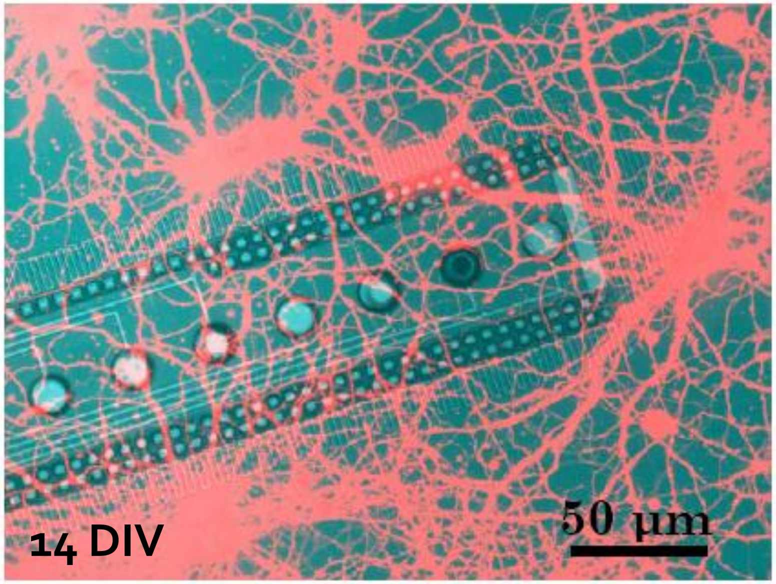


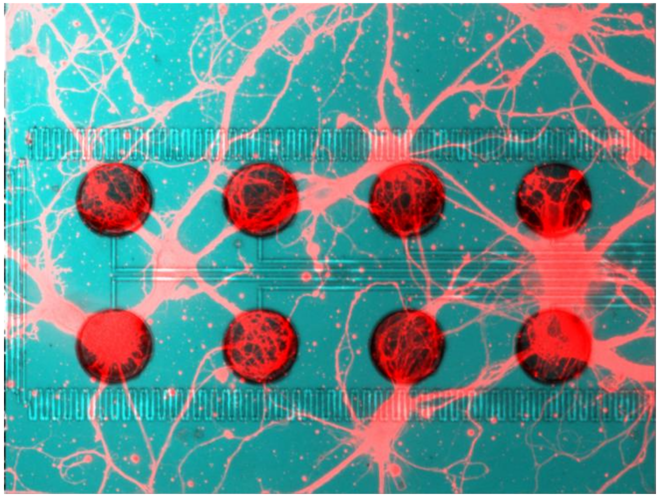




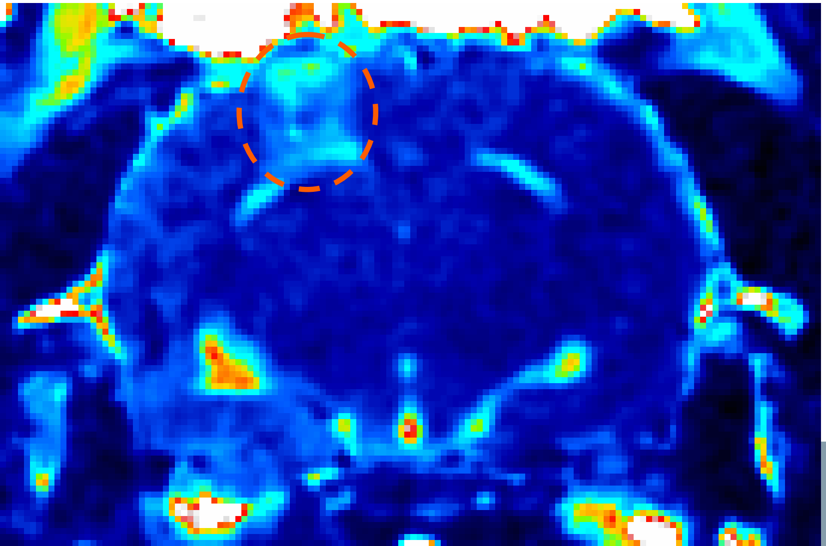


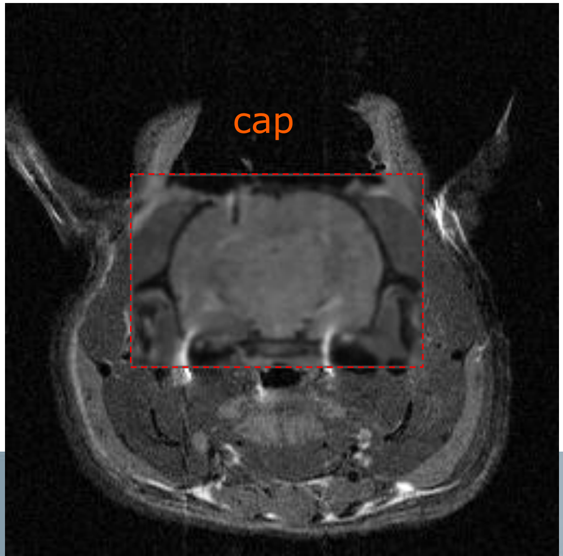
Achieving compliance for (bio)medical use: Biocompatibility, MRI compliance, insertion behavior

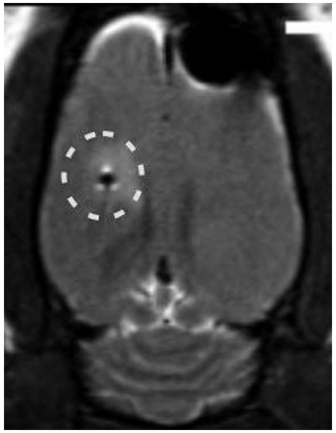




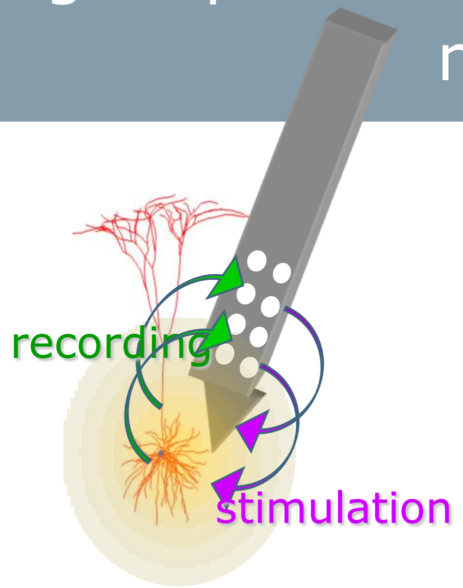
with KULeuven

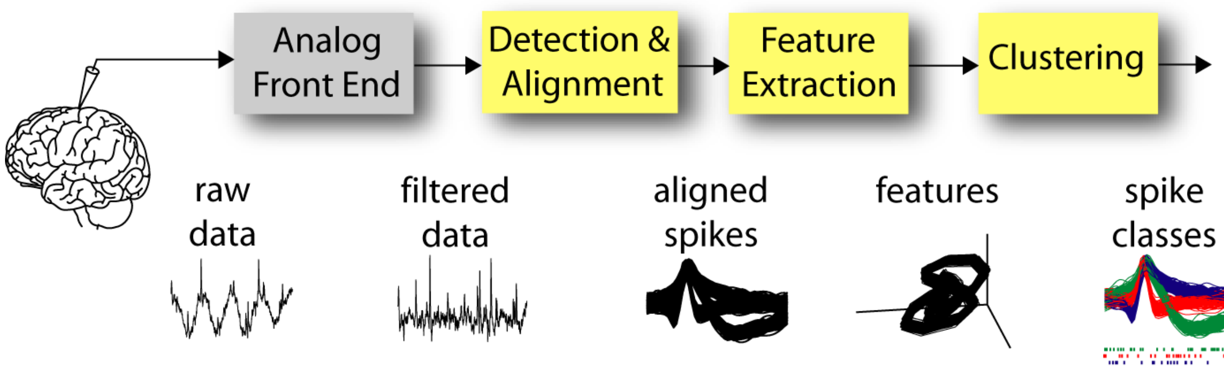


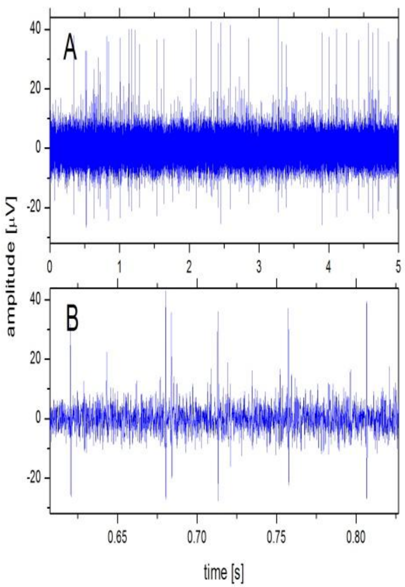


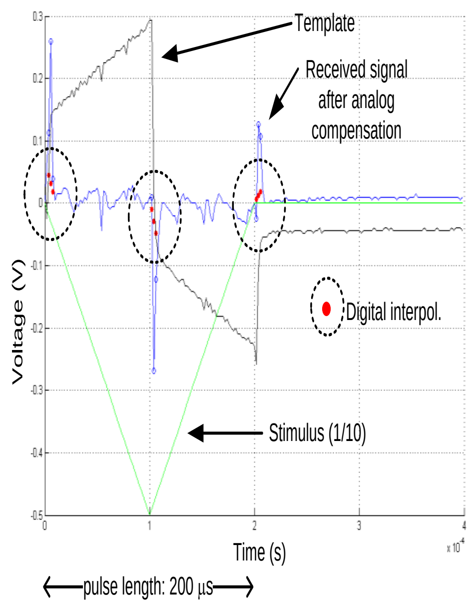


Signal processing & electronics for simultaneous multi-channel recording & stimulation

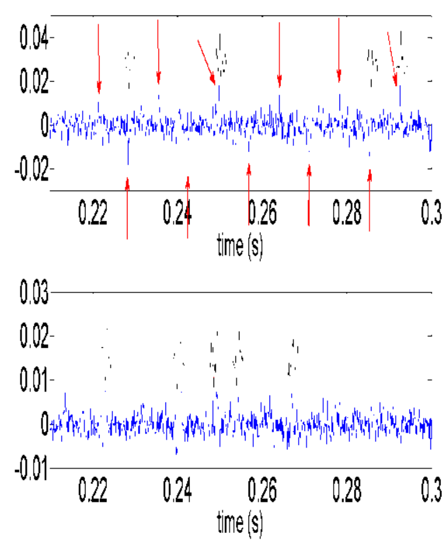




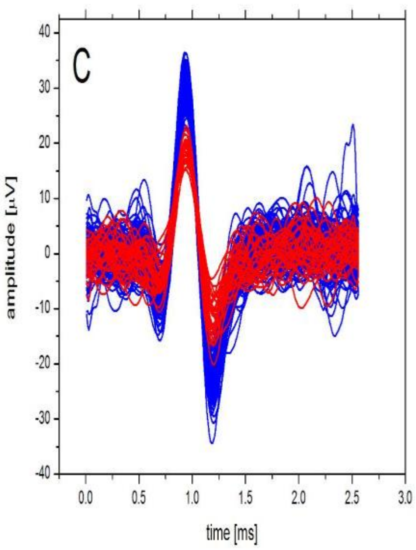




with KULeuven

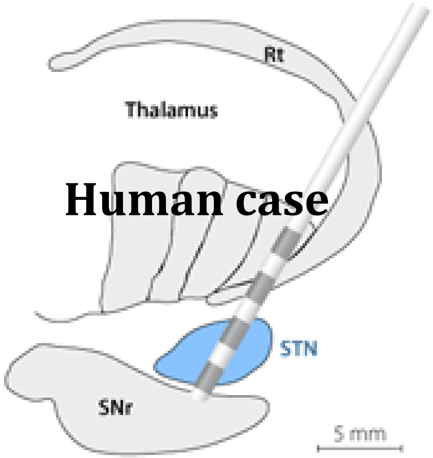


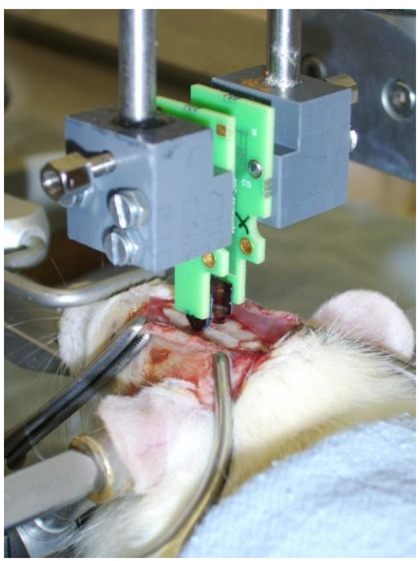
with KULeuven



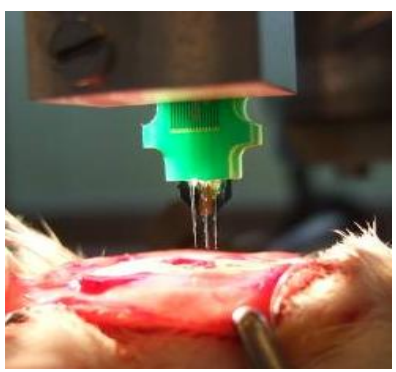
From components to a fully integrated implantable micro system for small animal (and human) use

Human case

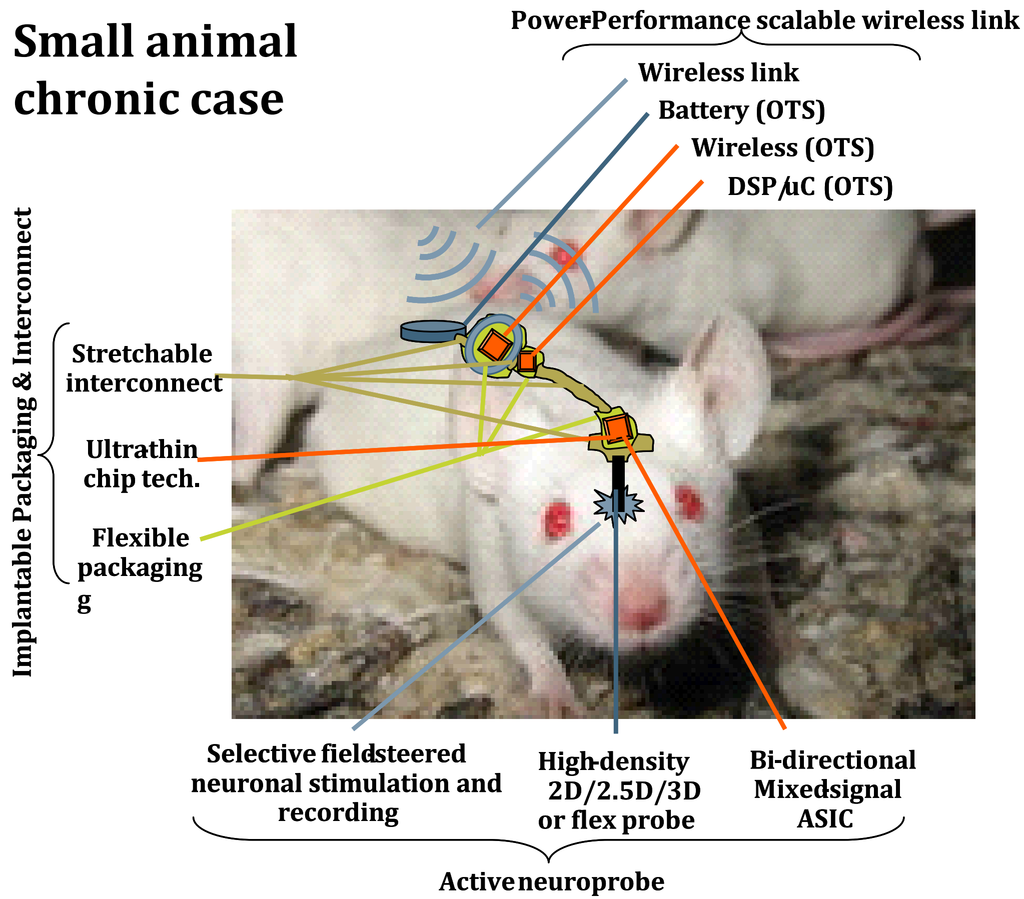




Small animal Acute case



Small animal chronic case



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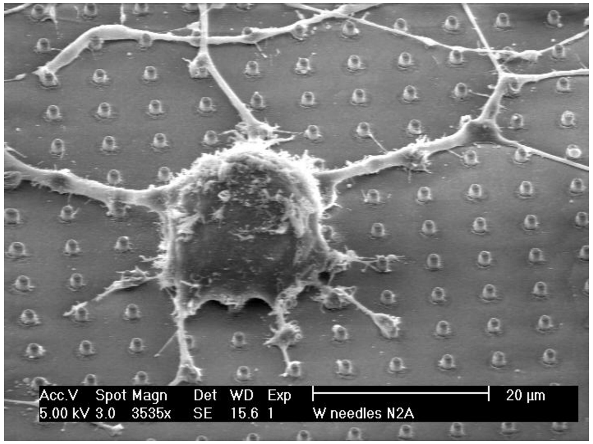
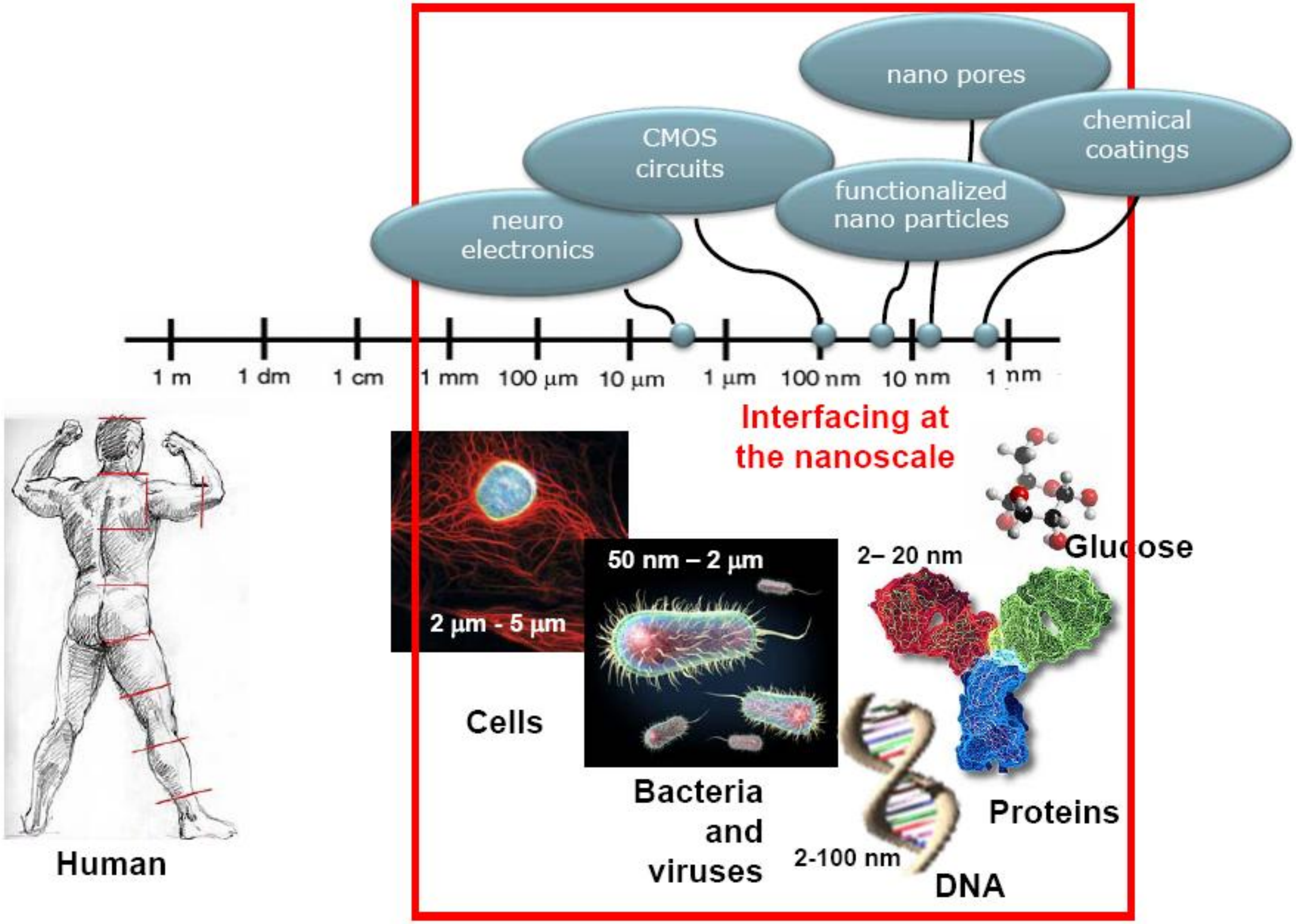
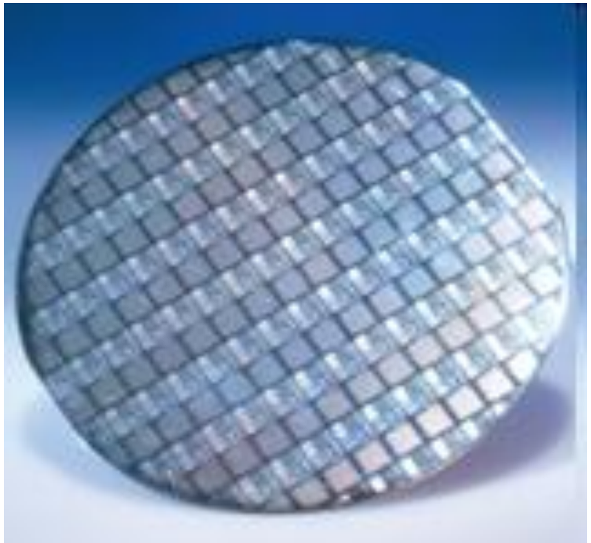
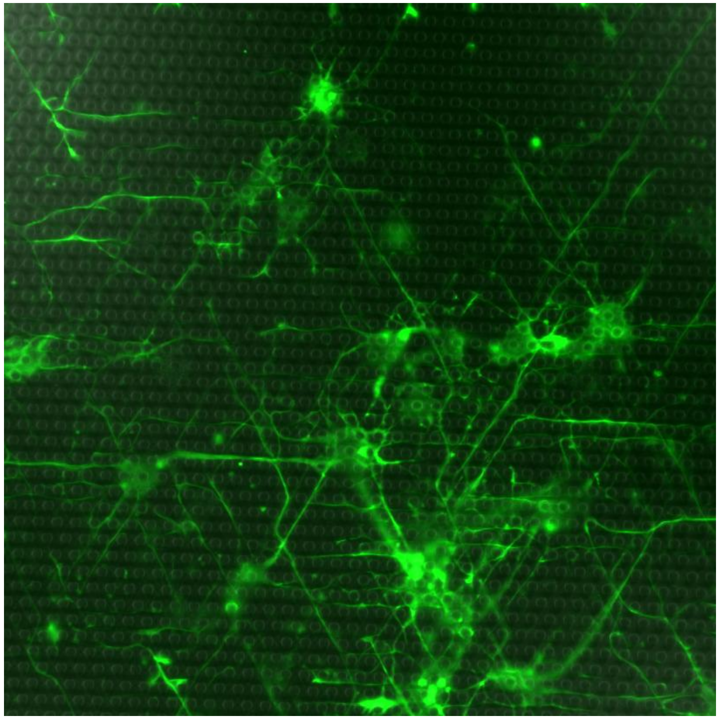


Why does the merger make sense?

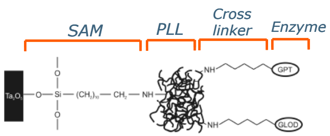


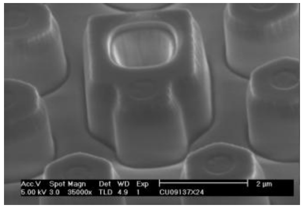
Micro- and nanoelectronics <-> Biology

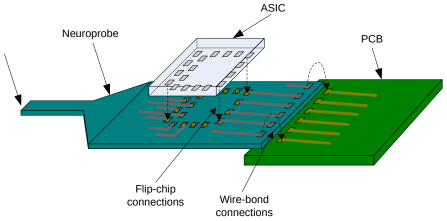


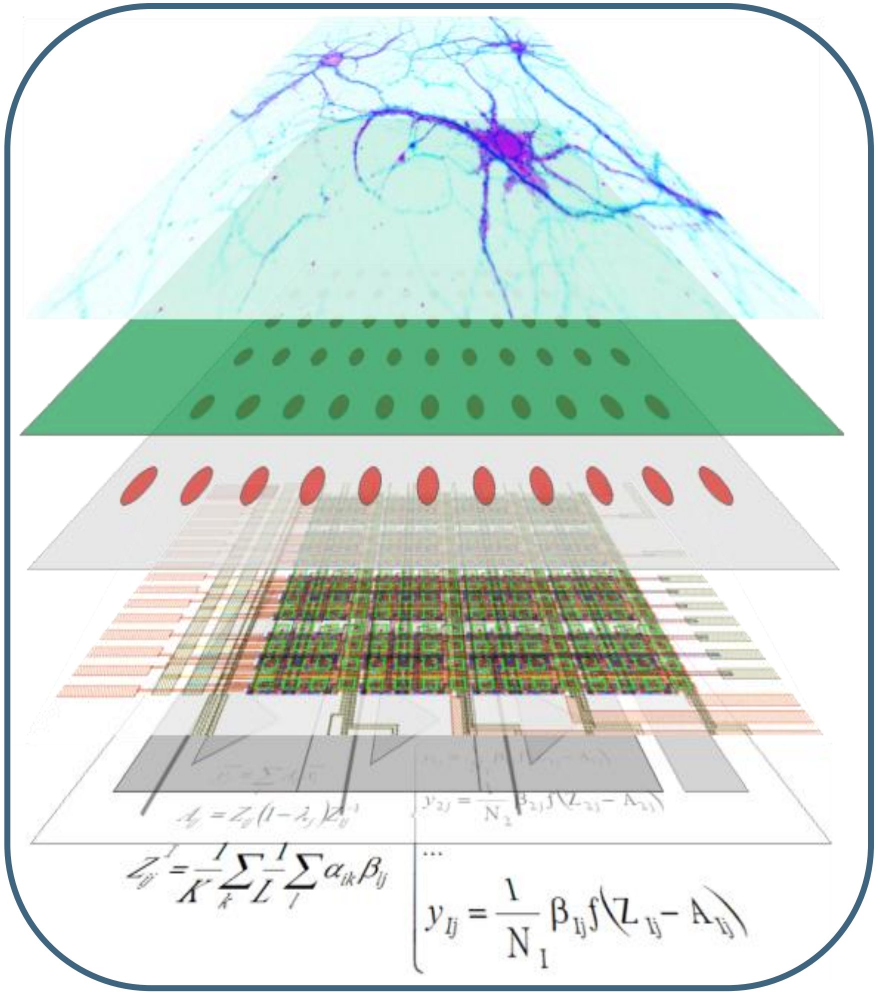


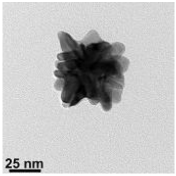
Technology paves the way from cell to computer

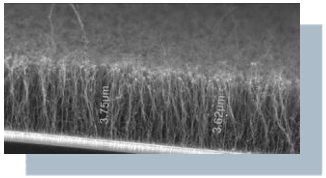


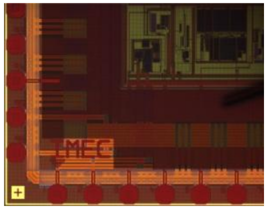


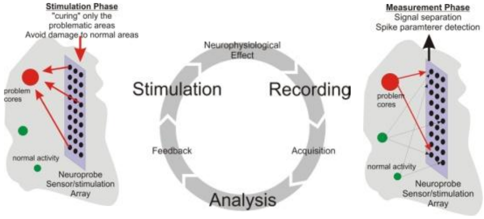




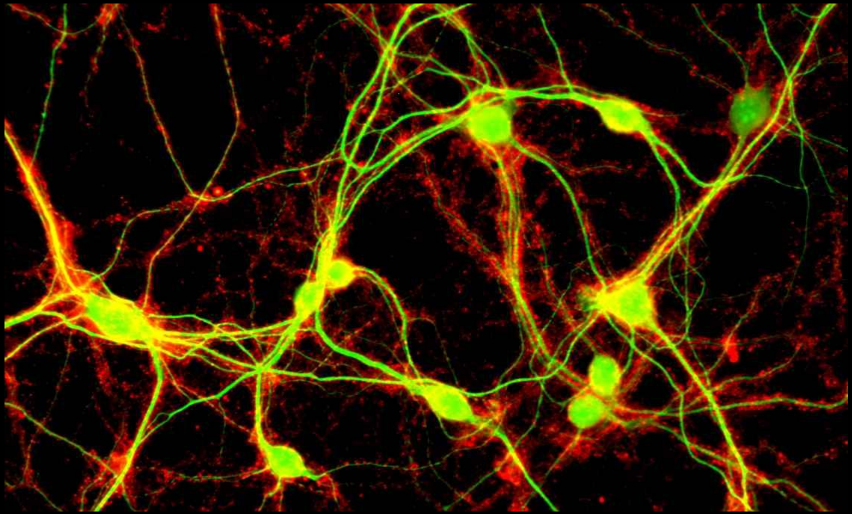




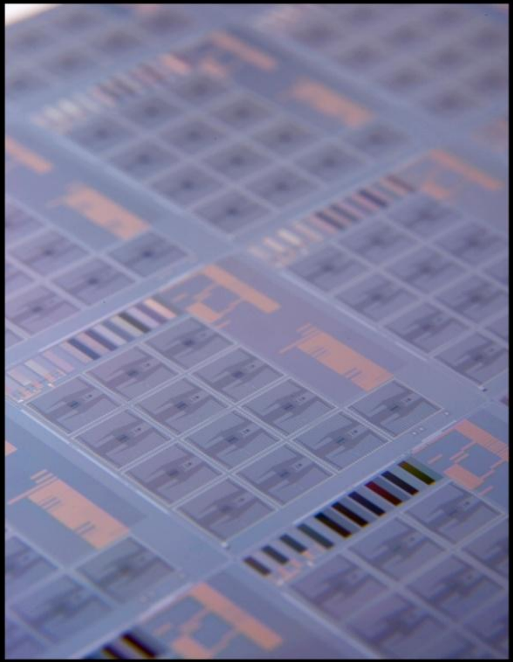




Via functional cell-IC interfacing towards novel in vitro and in vivo tools for life sciences and healthcare



signal

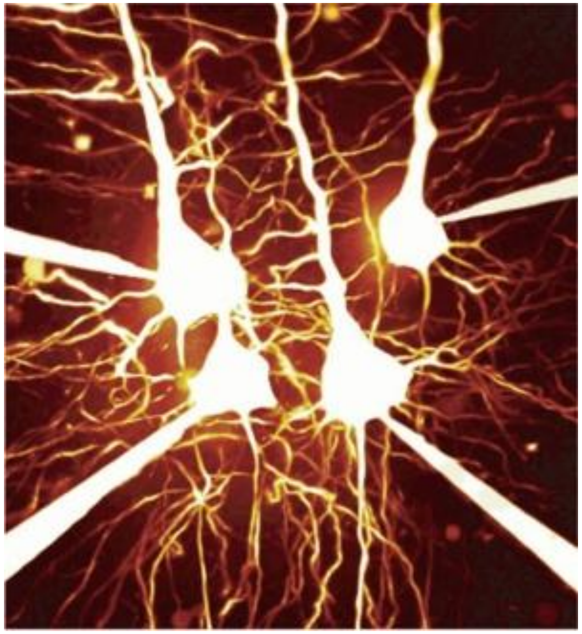


NanoIONICS

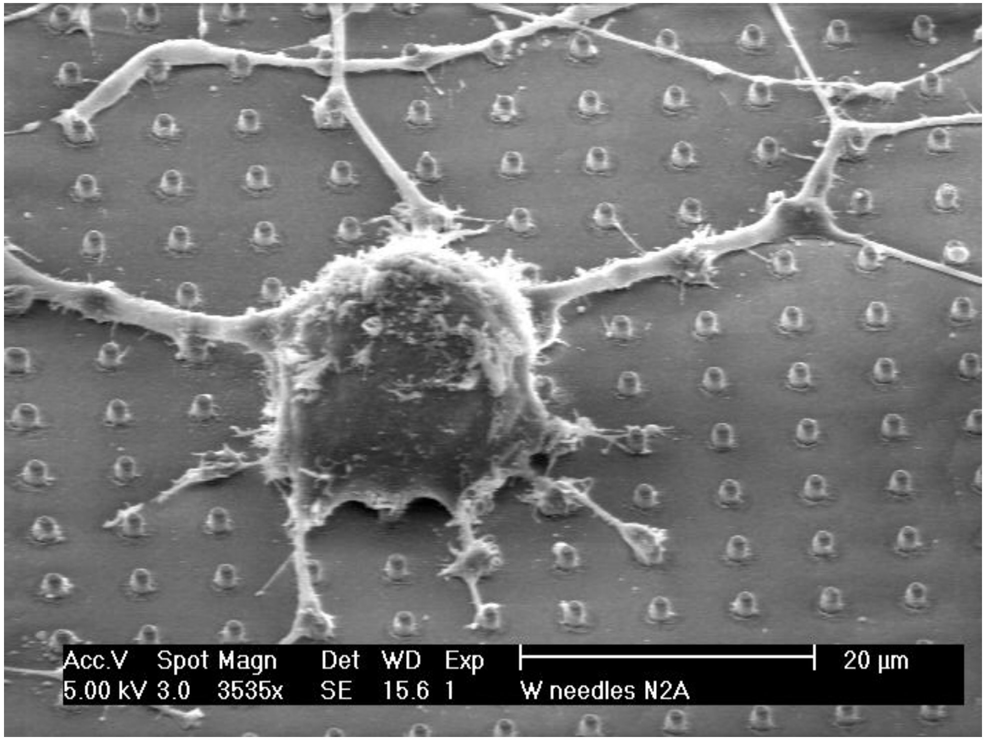
NanoELECTRONICS

VISION: *in vitro*

- From classical neuroscience to probing and controlling the brain at the level of a single cell and even single synapse



Classical method
(patch clamp)



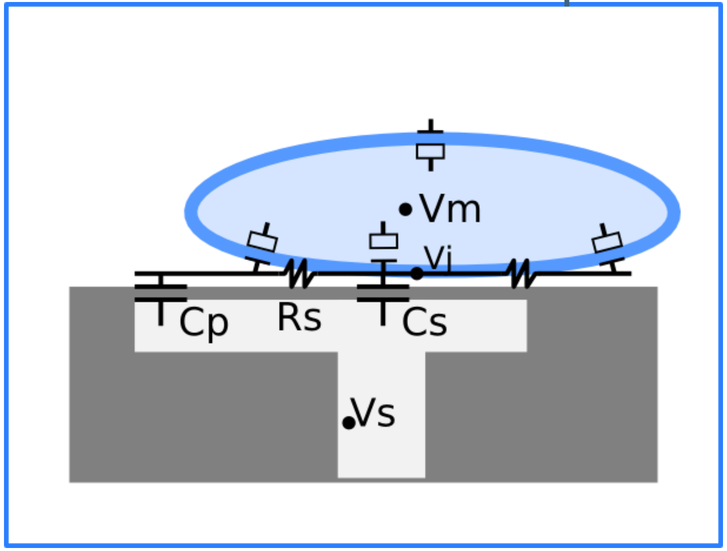
IMEC approach

3D electrodes: nails

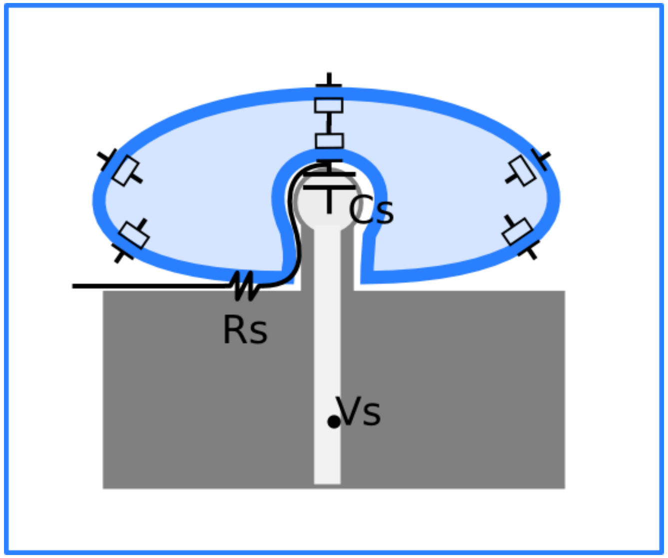
Flat vs. nail-like:

- Increase electrode-membrane coupling
- Increase R_{seal} → better signal quality

Classical planar

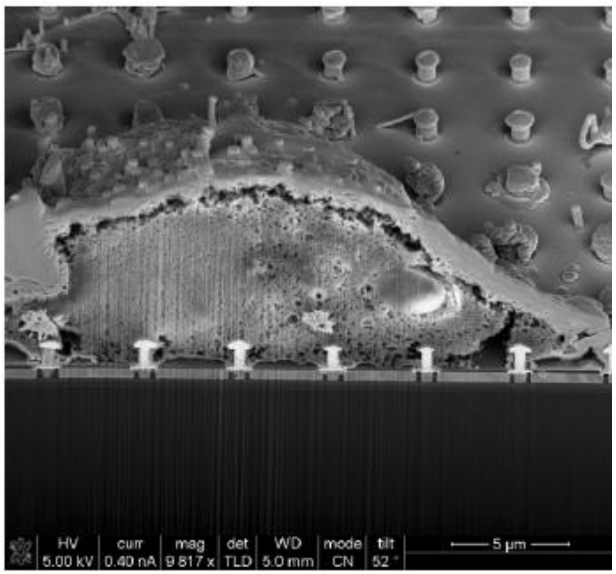


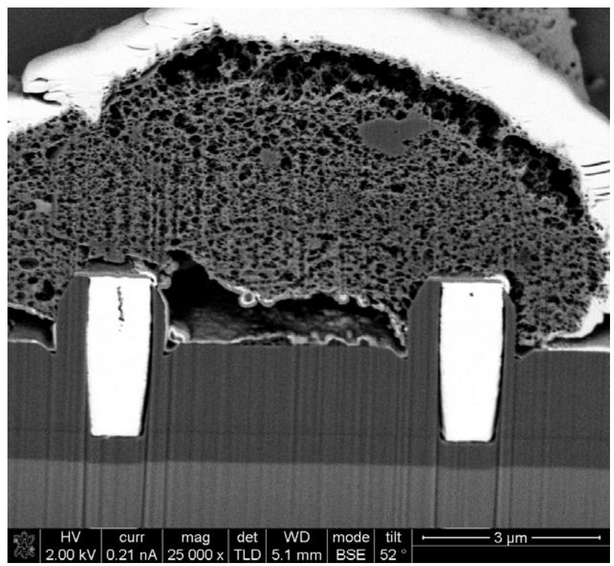
IMEC

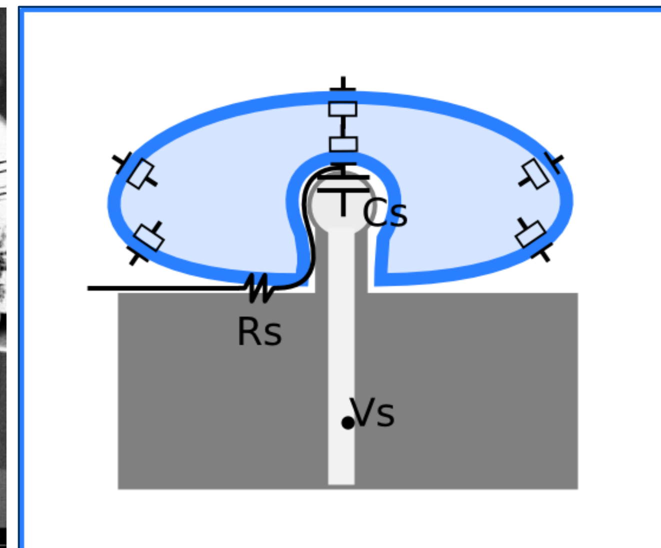


Tuning hardware to fit biology

- Replace planar electrodes with ***3D cellular probes***





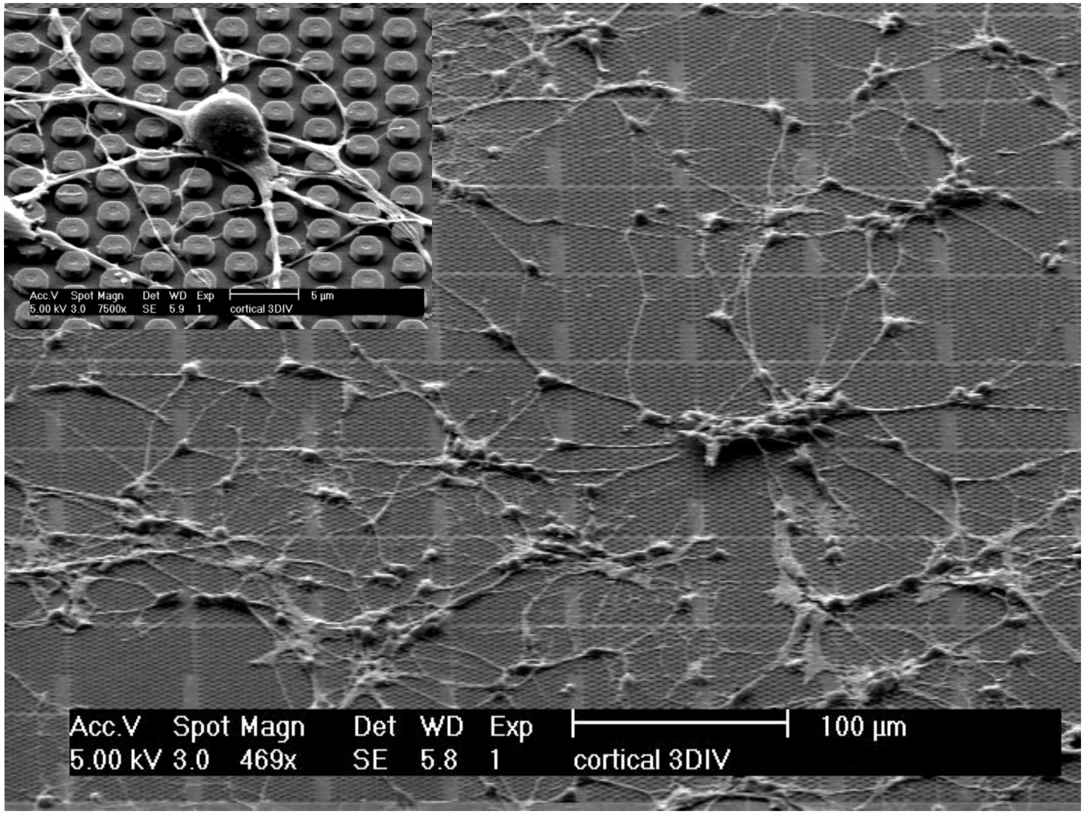


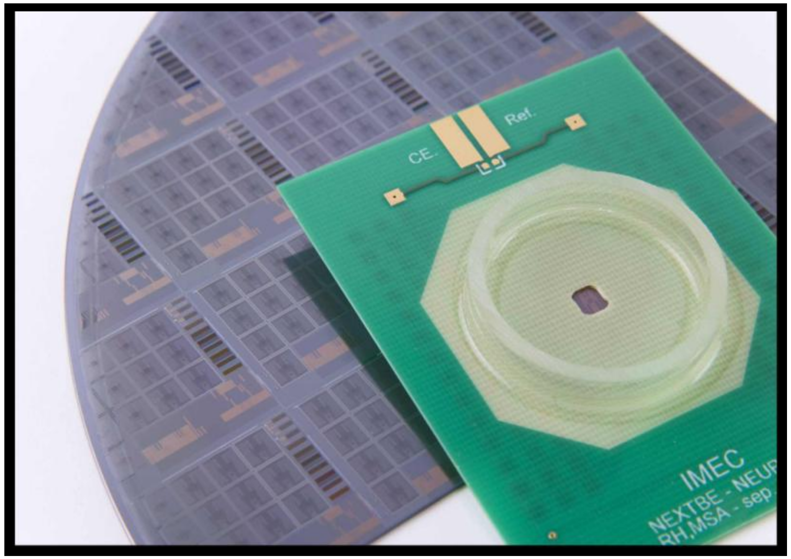
On chip "ENGULFMENT"

Improved signal coupling
(reduced signal leakage,
reduced parasitics)

Applications: *in vitro*

- R&D tools for basic science (e.g. understanding cellular signaling, communication, disease mechanisms)
- Drug screening
- Biosensors
- Actuation and sensing of prosthesis

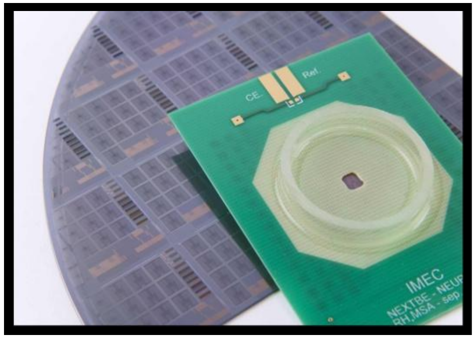


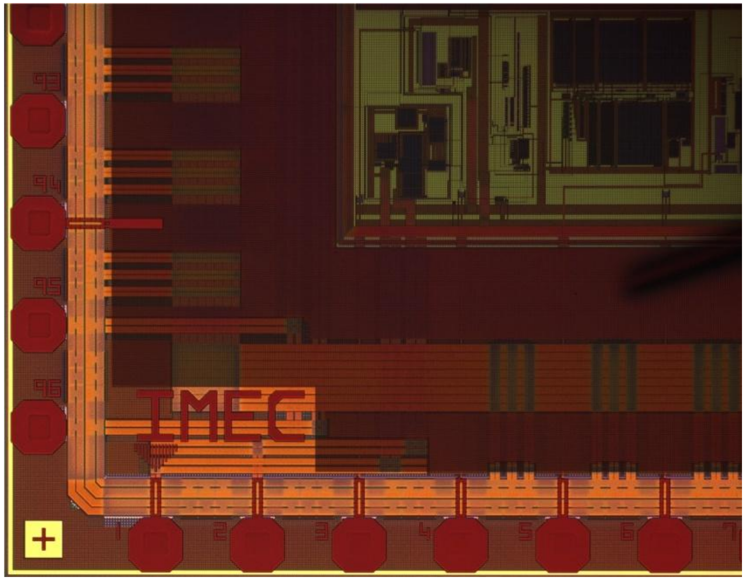


IMEC's NEURAY chip

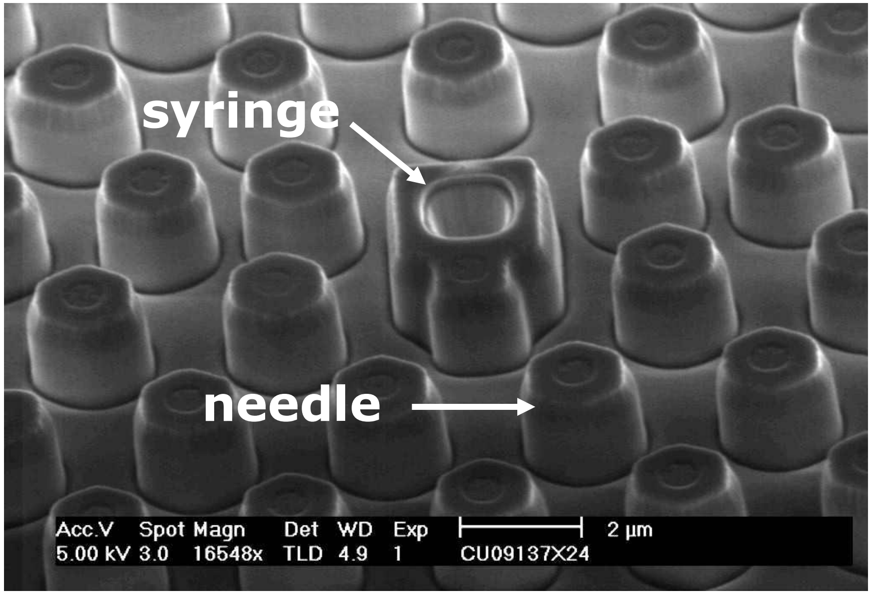
Tuning hardware to fit biology

- Full system integration (customized for application)



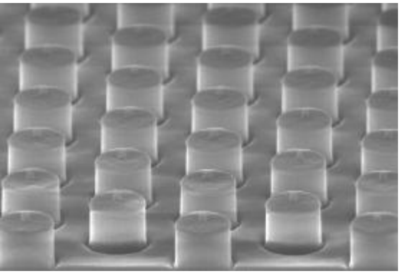


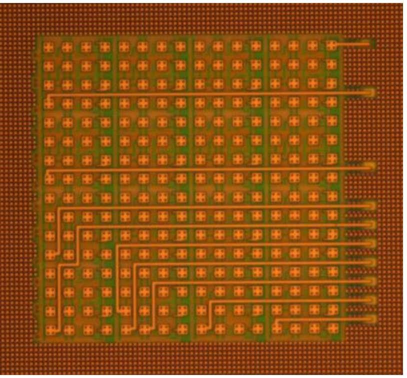
CMOS readout/control electronics
In situ amplification
TSMC 0.18 μm technology

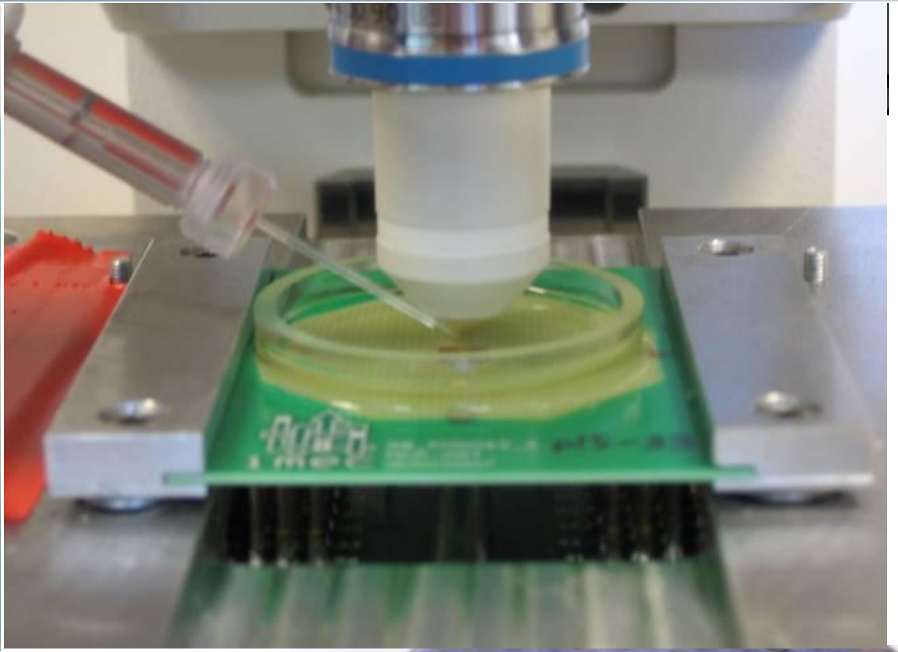


Cellular probes: needles & syringes

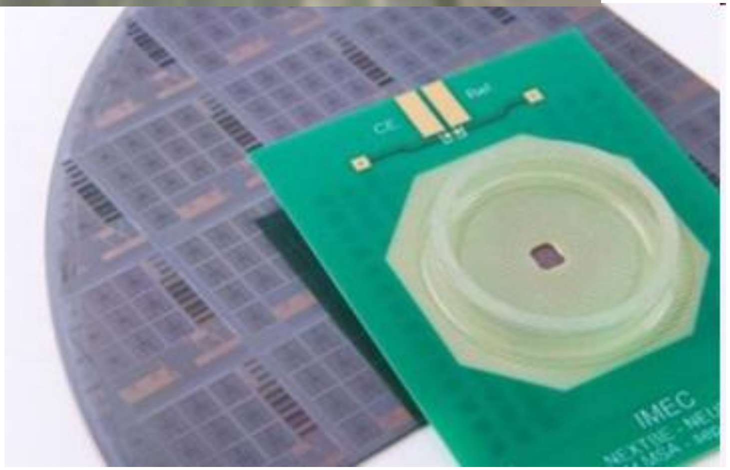
From technology to the complete prototype system for *in vitro* micro nail array recording & stimulation





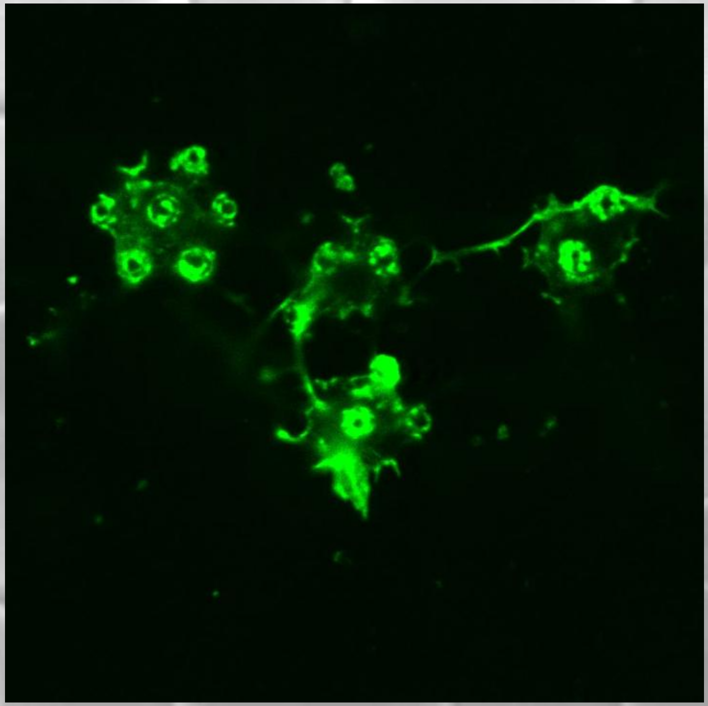


- Process development for nails
- CMOS design
- Packaging
- System setup

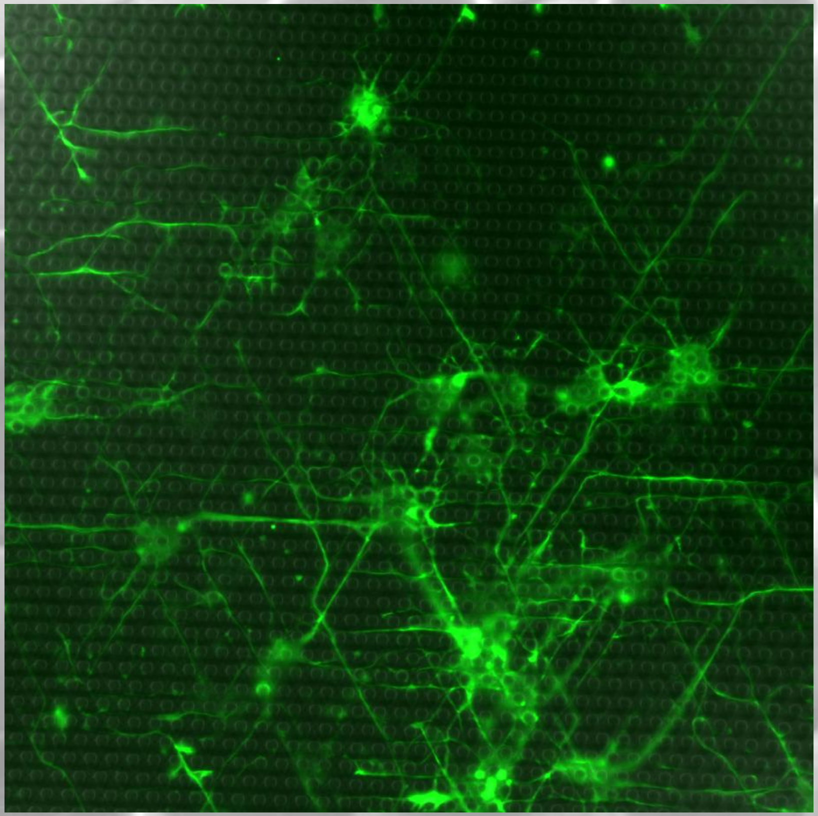


Cellular responses

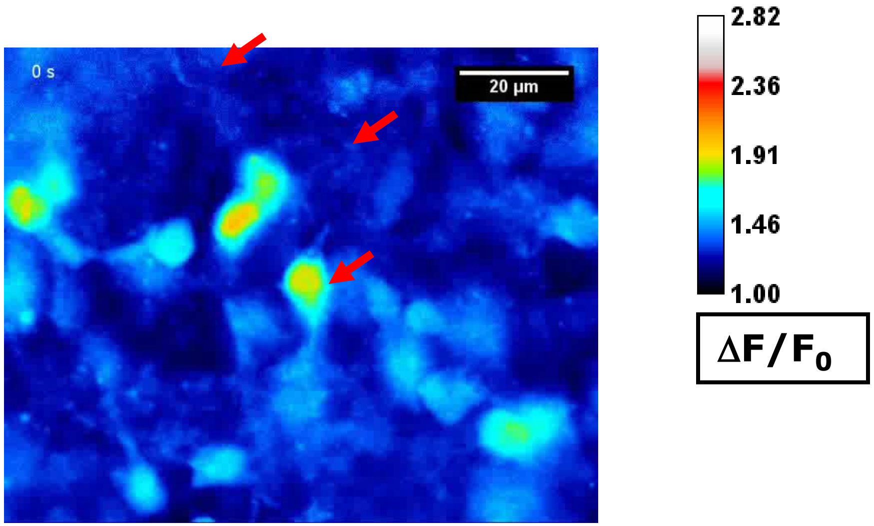
Increased actin concentration around nails → ENGULFMENT

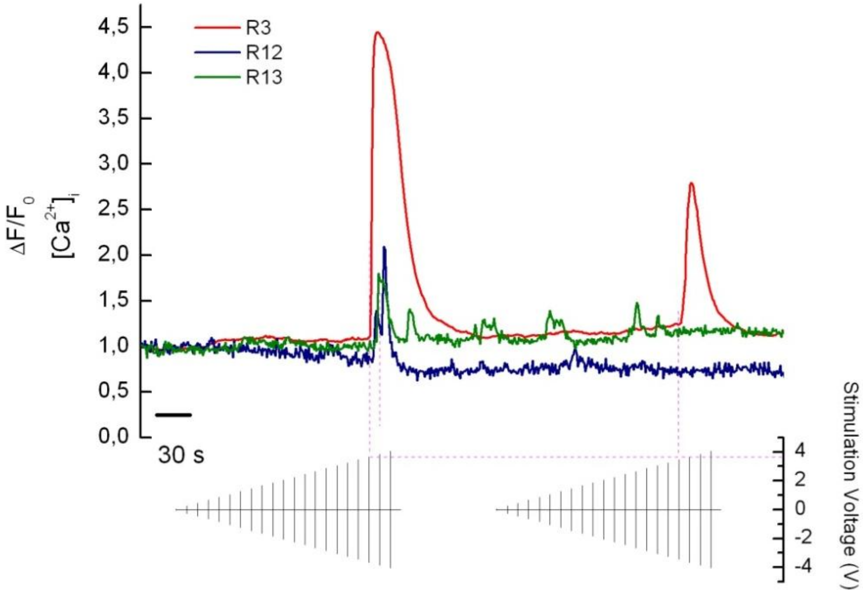


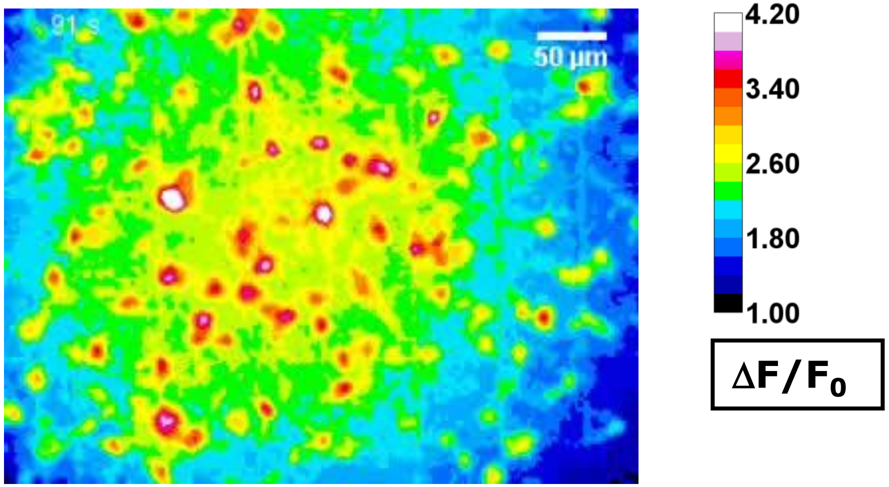
Axon guidance due to nail spacing → CELL TAXIS

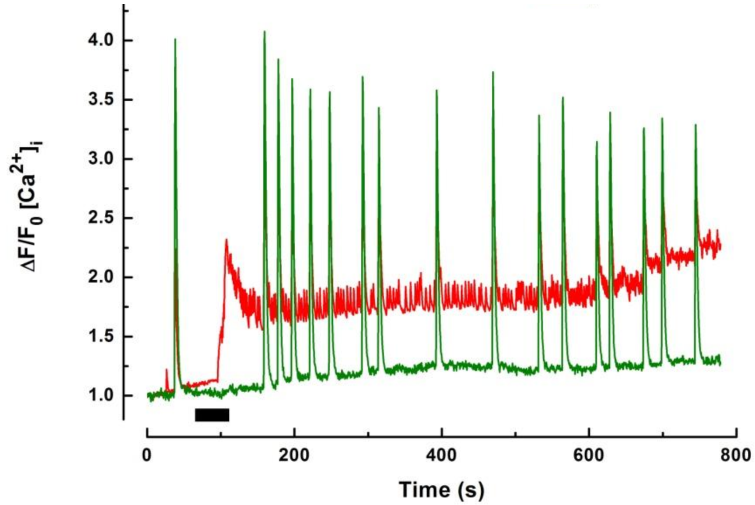


Localized neuronal stimulation









Overview

Why interfacing computers to the brain?

System level interfaces

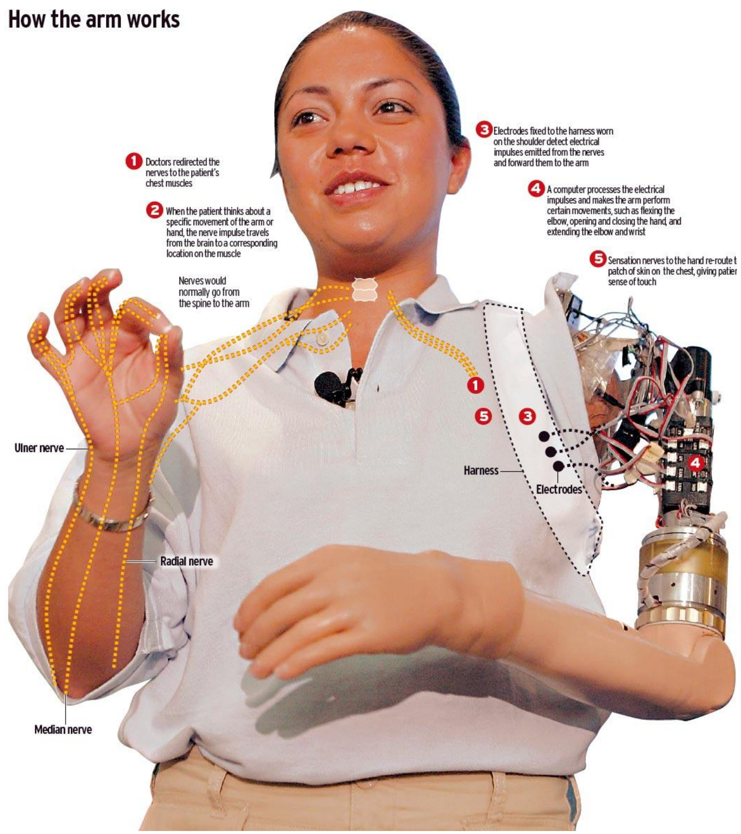
Macro level interfaces

Micro level interfaces

From Science Fiction to Science Fact?

From micro-level in-vitro to in-vivo…

Sensing and steering individual neurons will enable
the coupling of prostheses to the human nervous system



From micro-level in-vitro to in-vivo… and back to in-vitro: the scary part

Will the data centers of the future look like this?