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CNIT PARIS LA DÉFENSE
FRANCE
JOURNÉES INTERNATIONALES DE BIOLOGIE
Journées Scientifiques Nationales de la SFBC
Journées Scientifiques

Labopuce implantable sous cutanée: un mini-laboratoire sous la peau

Lab-on-a-Chip implants: a mini-lab under the skin

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nano-tera.ch

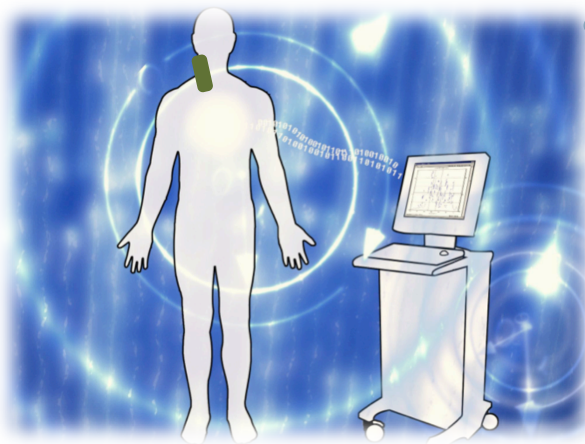
ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

Outline

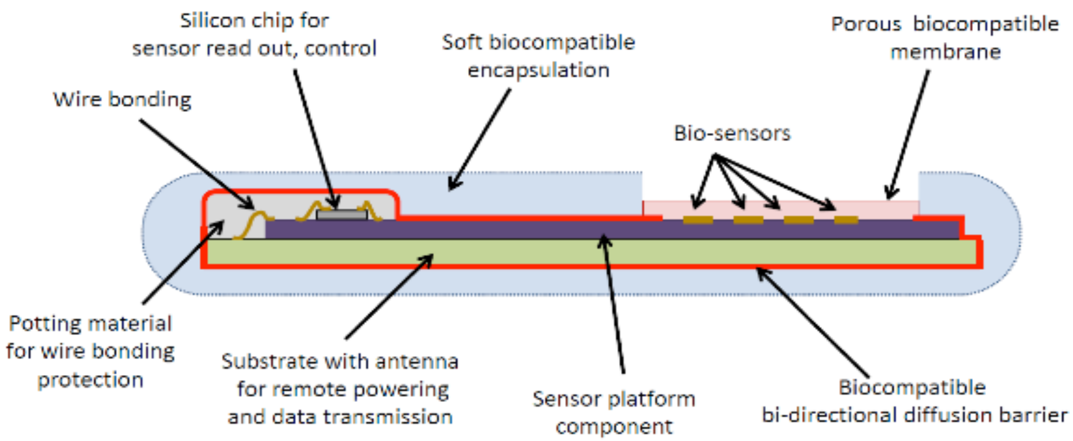
- Motivation, objectives and overview
- The *nanobiosensor* technology
- Control and readout circuit for multi-target biosensing
- Microelectronic circuits for data acquisition and energy harvesting
- System biocompatibility
- Conclusions and outlook

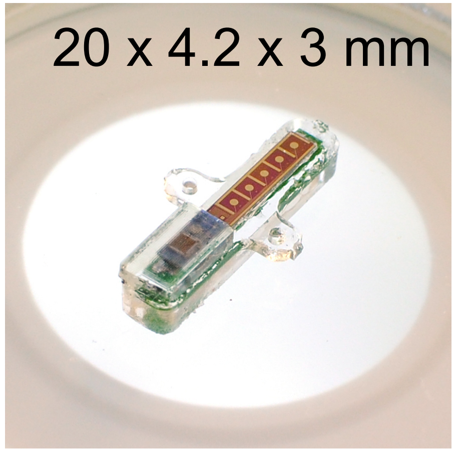
Objectives

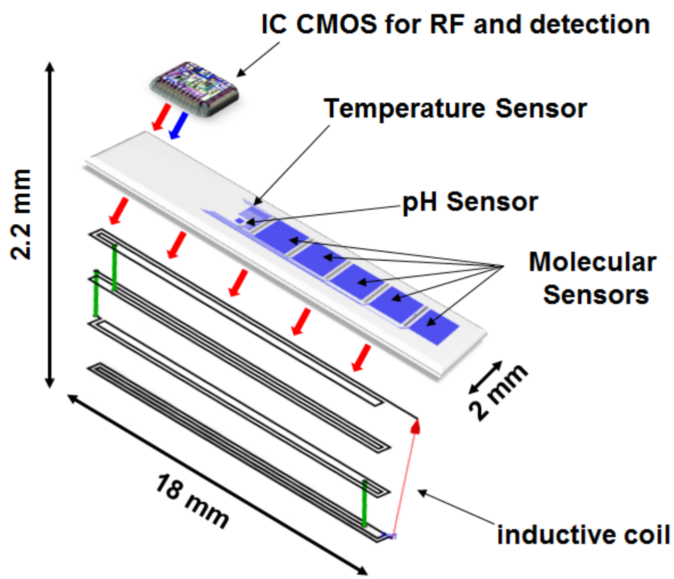
- Continuous real-time monitoring of chronic patients
- Current devices are external and limited to a single measurement
- Tracking multiple metabolites
- Wireless, batteryless implant
- Driver technology for a wide set of applications

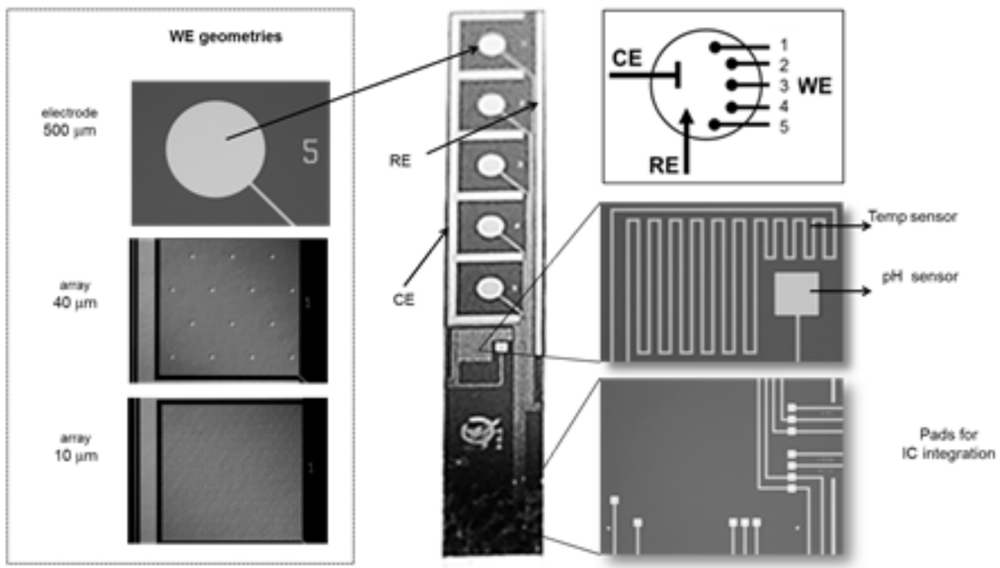


Prototype: implant

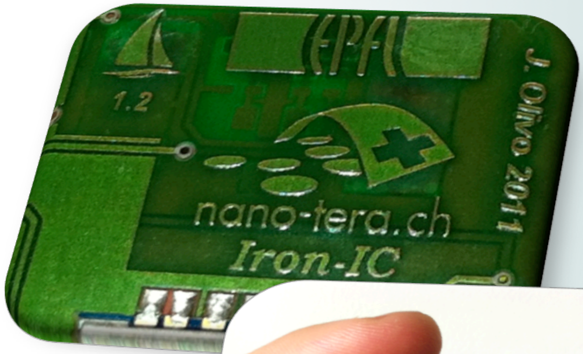


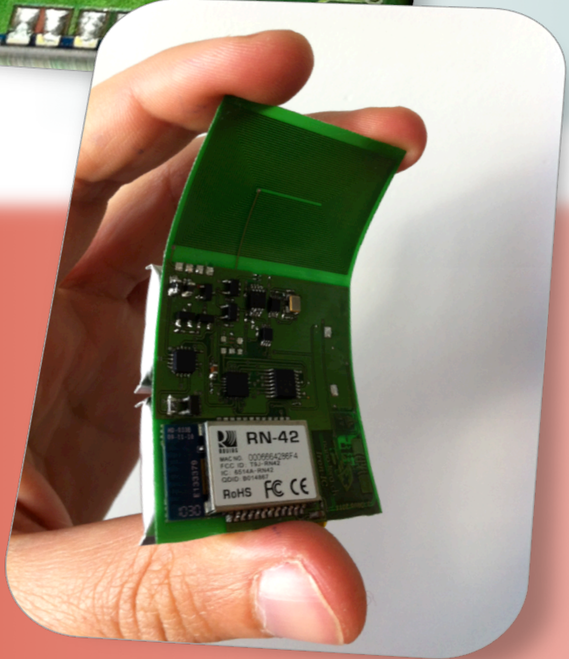






Prototype: external patch





FEATURES

Remote powering through inductive link

Short-range bidirectional communication

Long-range comm. with remote devices

ADVANTAGES

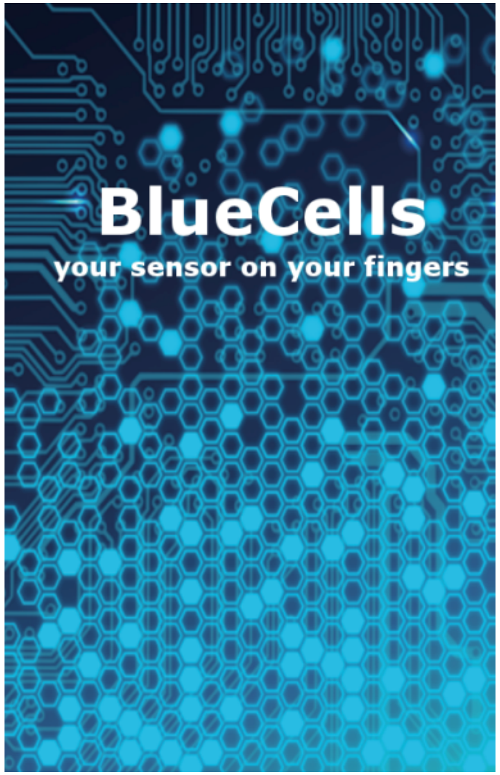
Improved wearability

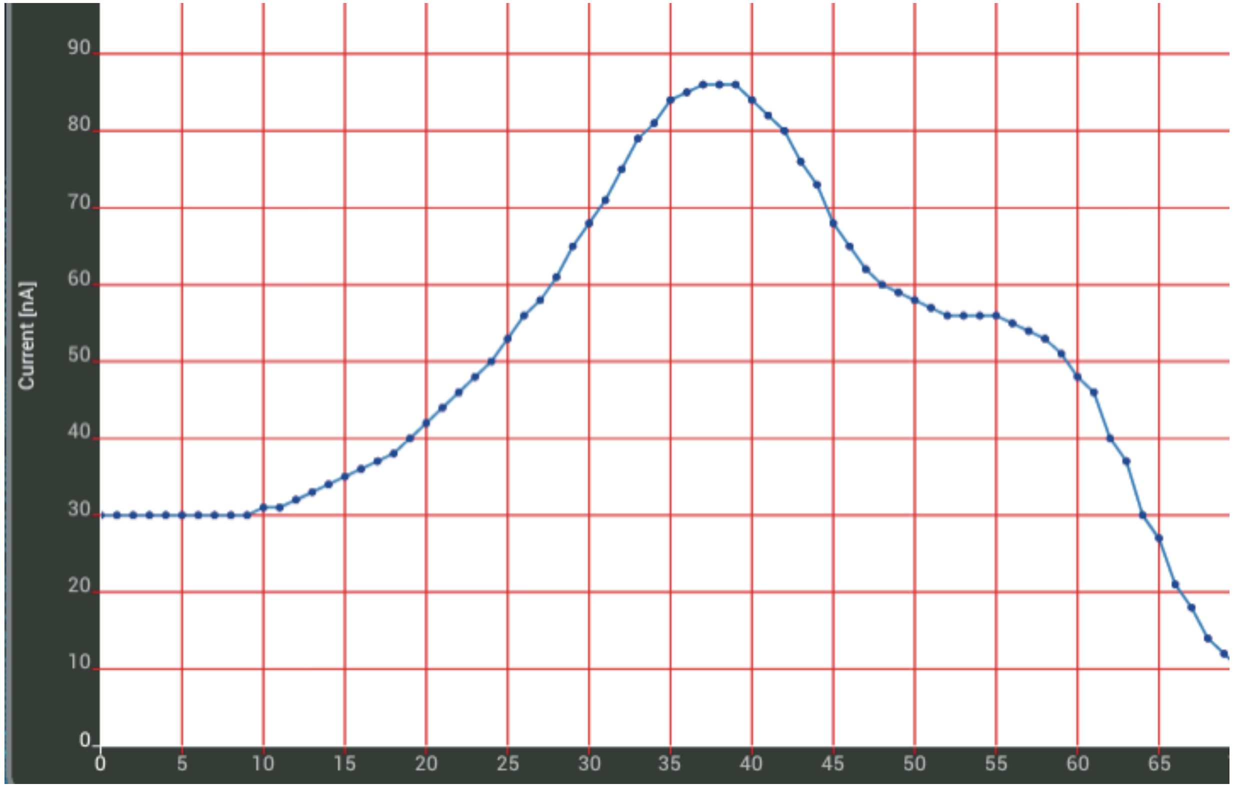
Direct placement over implant area

Stand alone

Battery-powered

Android User Interface





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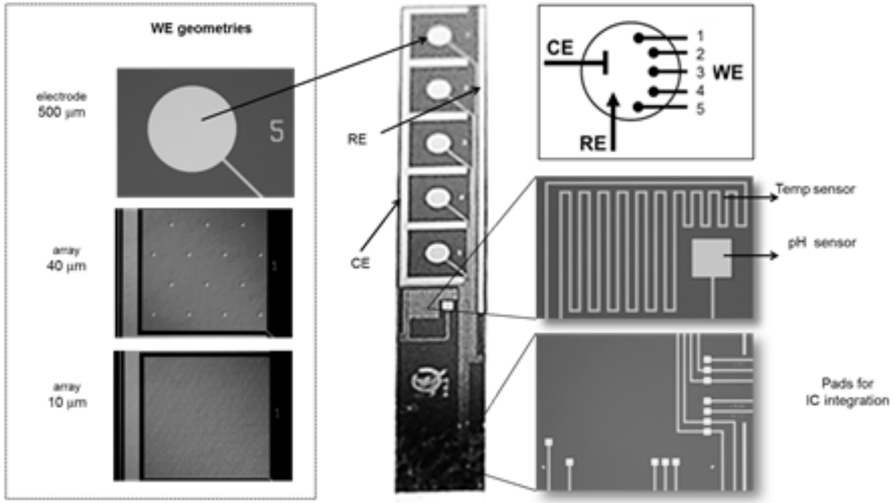
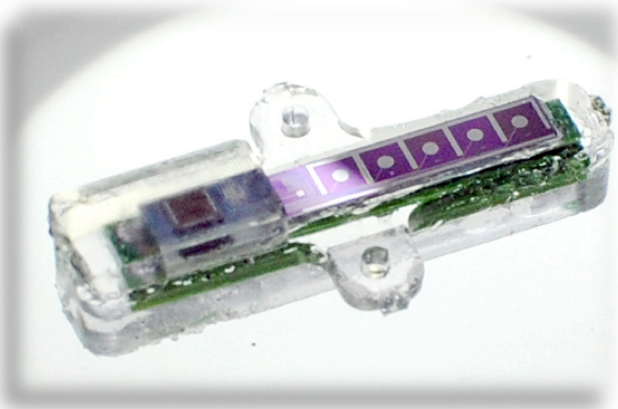
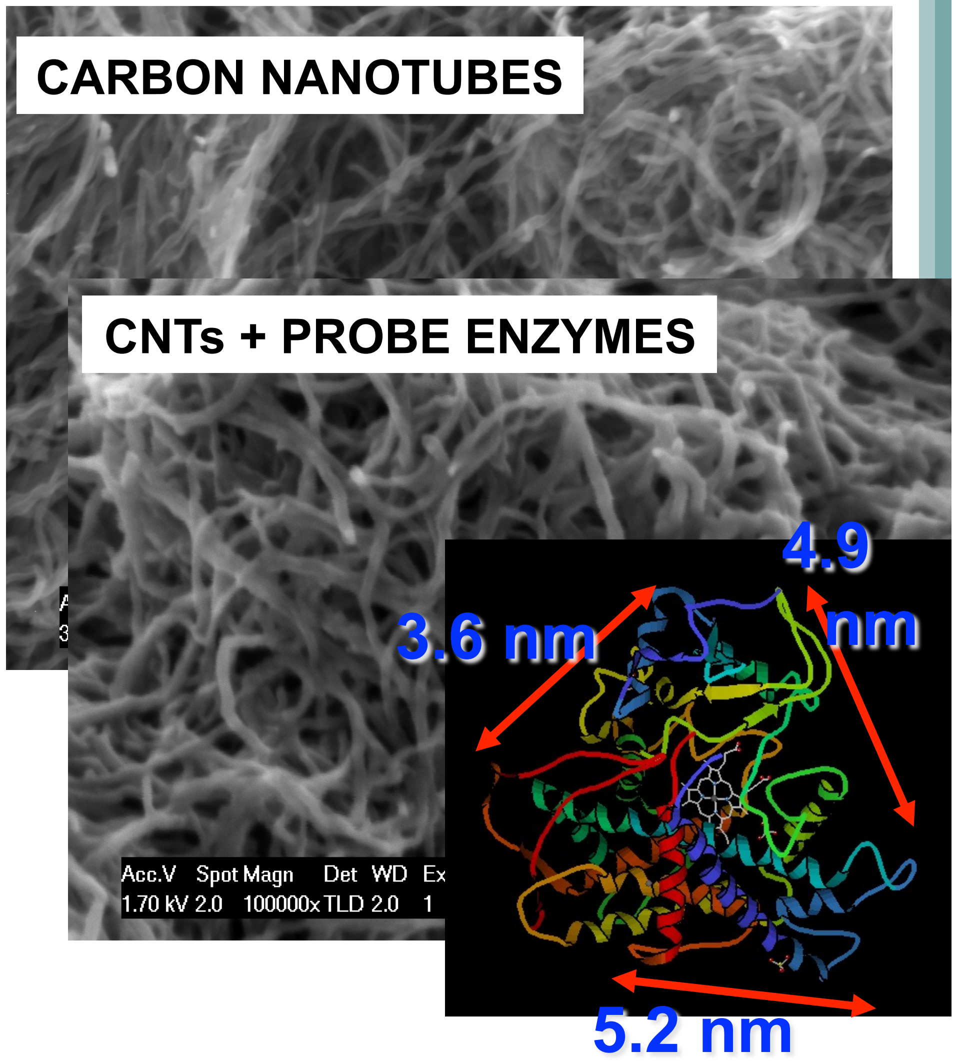
The *nano*biosensor concept

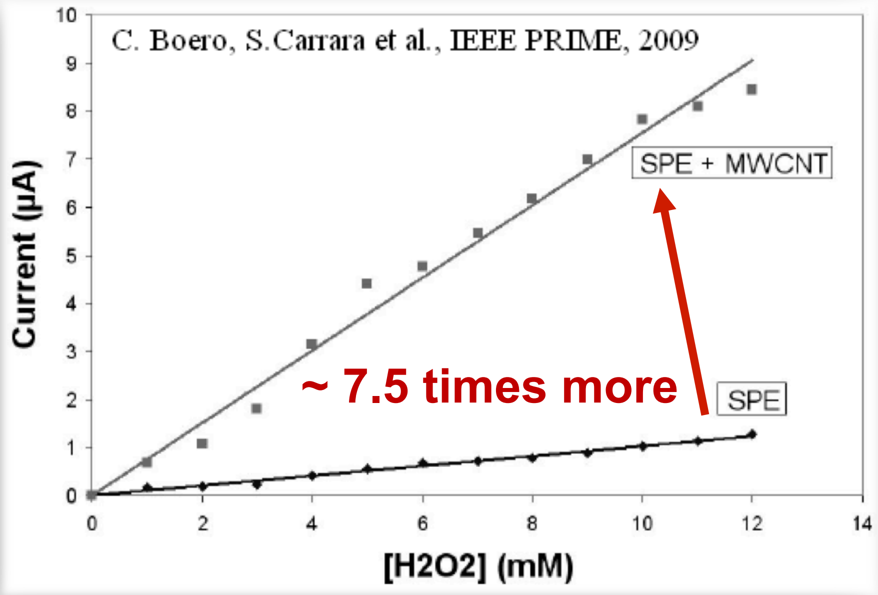


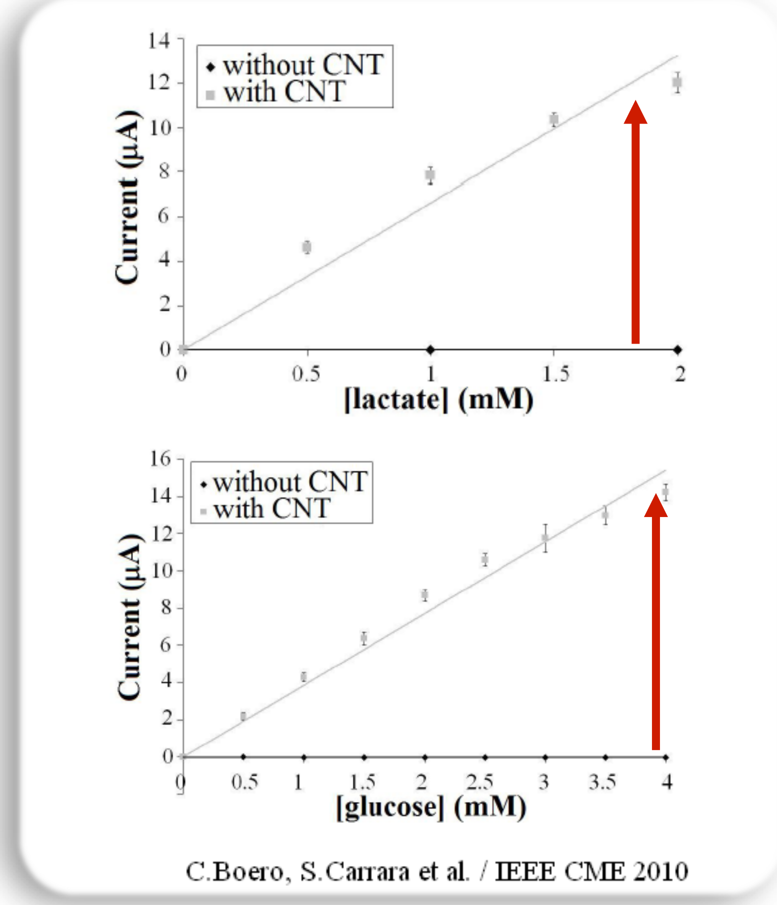




Carbon nanotube benefits

Sensor sensitivity is enhanced by CNT nanostructuration





Nanobiosensors sensitivity and range

Metabolite	Sensitivity ($\mu A/mM\ cm^2$)	Range (mM)	Detection limit (S/N = 3σ) (μM)
Glucose	27.7	0.5 – 4	73
Lactate	40.1	0.5 – 2.5	28
Glutamate	25.5	0.5 – 2	195
ATP	3.42	0.5 – 1.4	208

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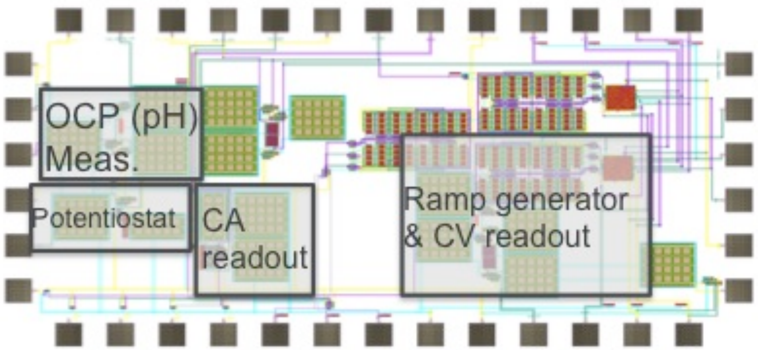
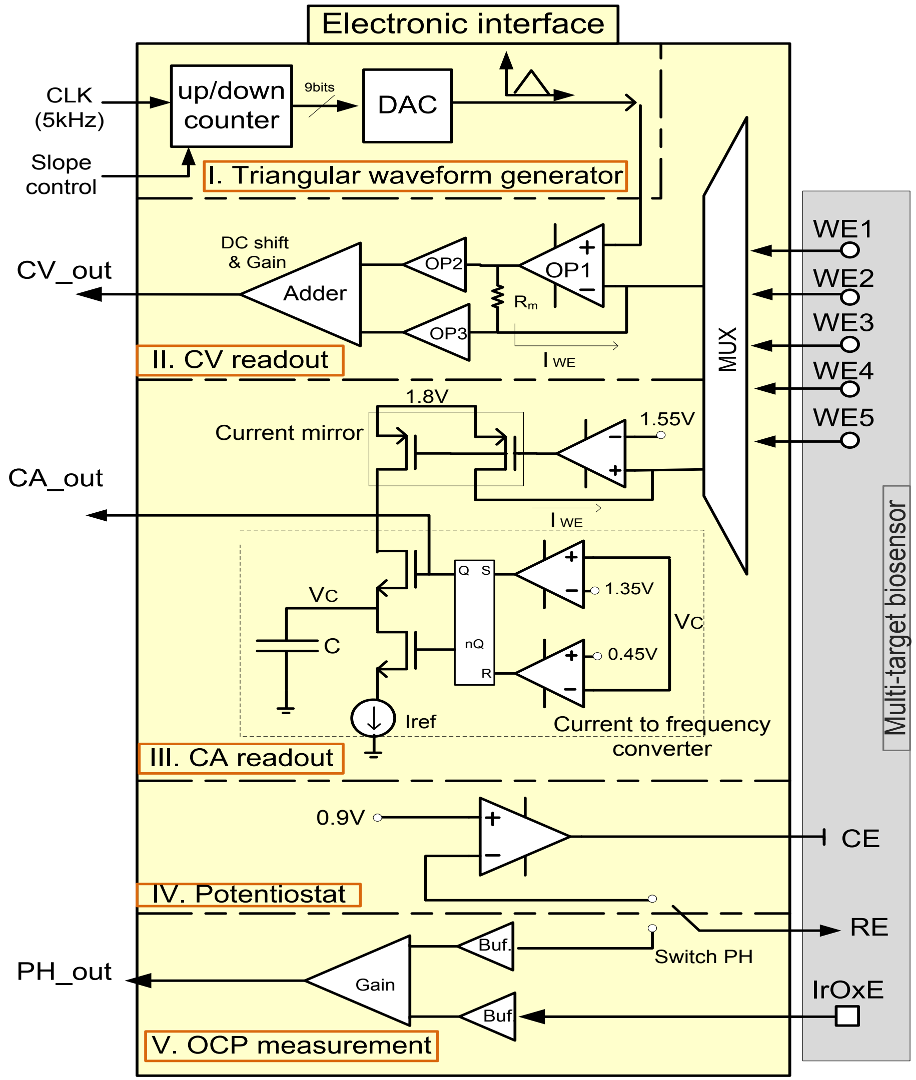
Control and Readout IC

- A biosensing **platform**
- Low power
- Remotely powered
- Flexible and programmable
- High accuracy



Layout of the fabricated IC
(0.18um technology)



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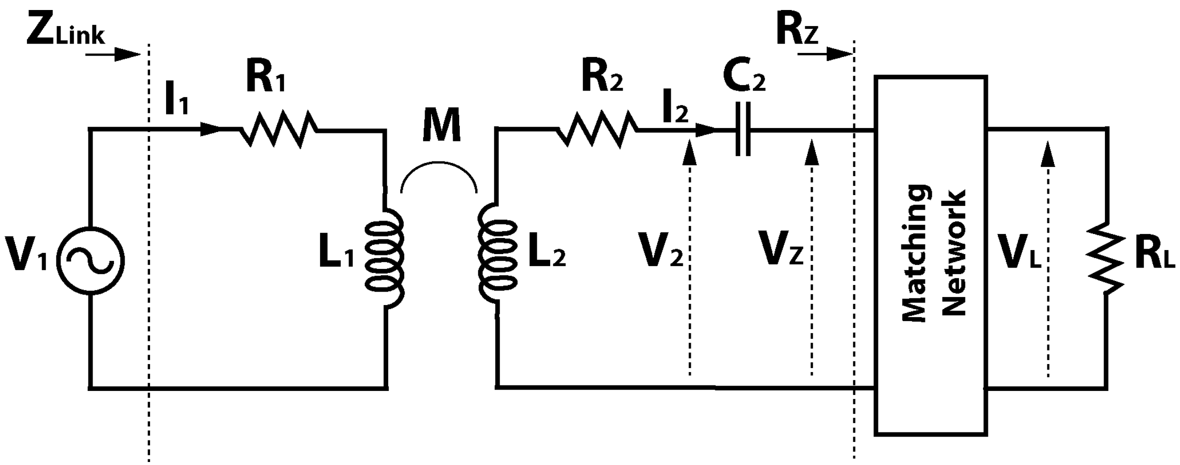
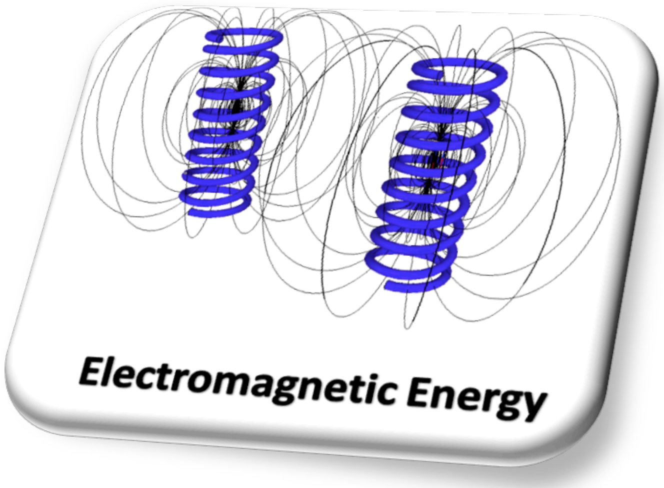
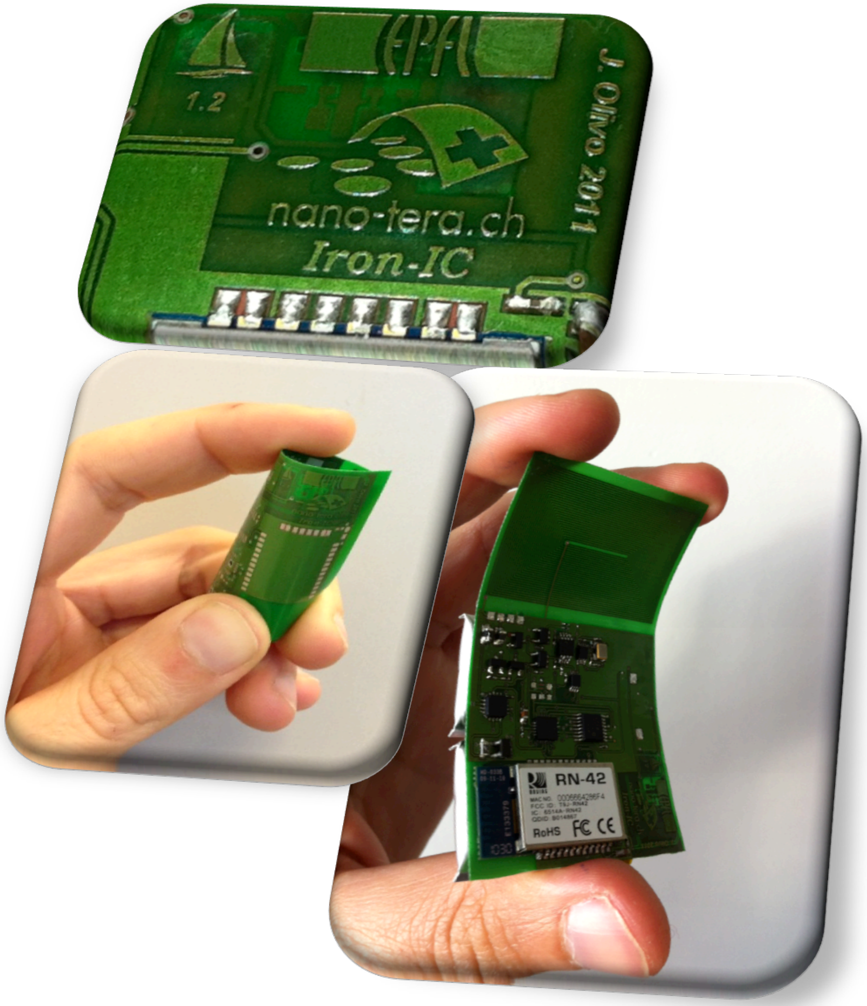
Inductive Link



- Wireless power transfer through inductive link
- Bidirectional data communication



IronIC Patch



Power Transmission

- Up to 15 mW transmitted within 6 mm in air
- Up to 1.2 mW transmitted within 17 mm tissue

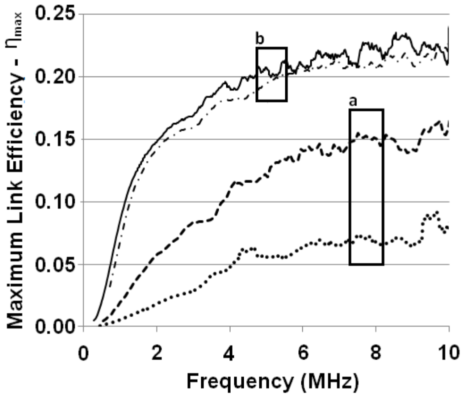
Data Transmission

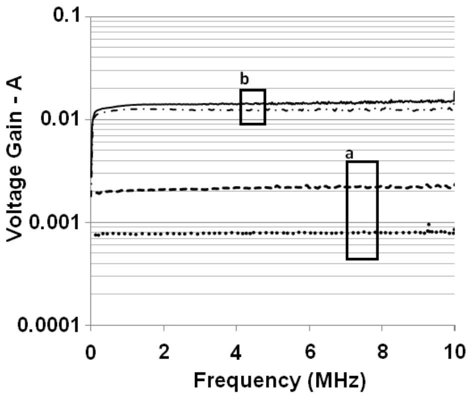
- Downlink communication up to 100 kbps
- Uplink communication up to 66.6 kbps
- Bluetooth communication (Class-2)

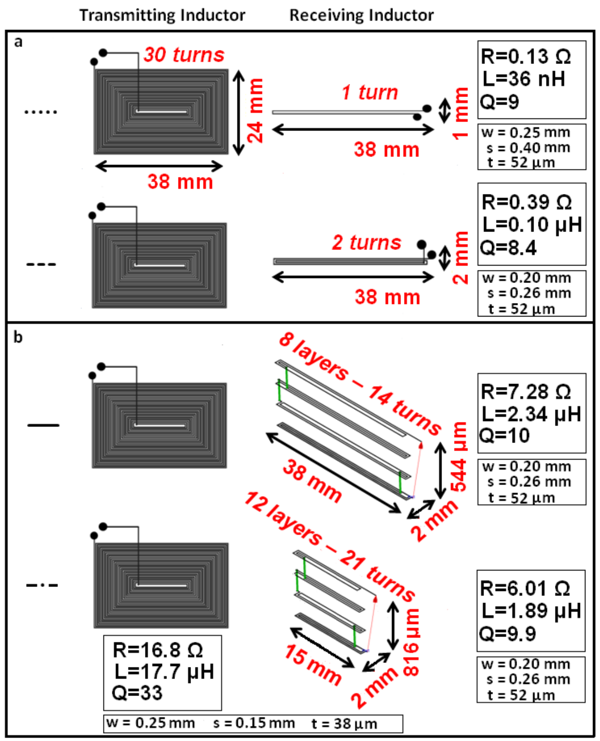
Battery Life

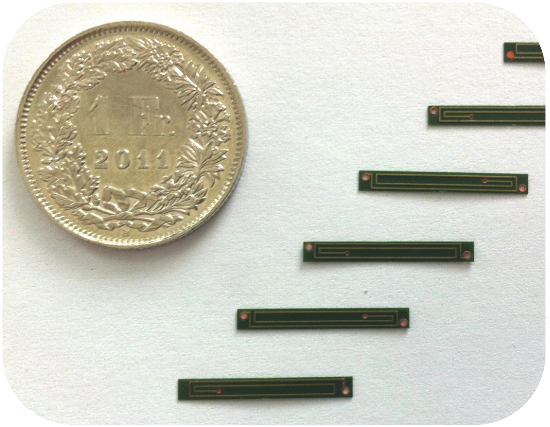
- Stand-by mode: 10 hours
- Power mode: 1.5 hours

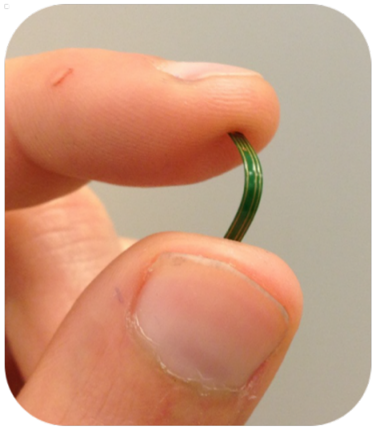
Multi-layer Receiving Inductors





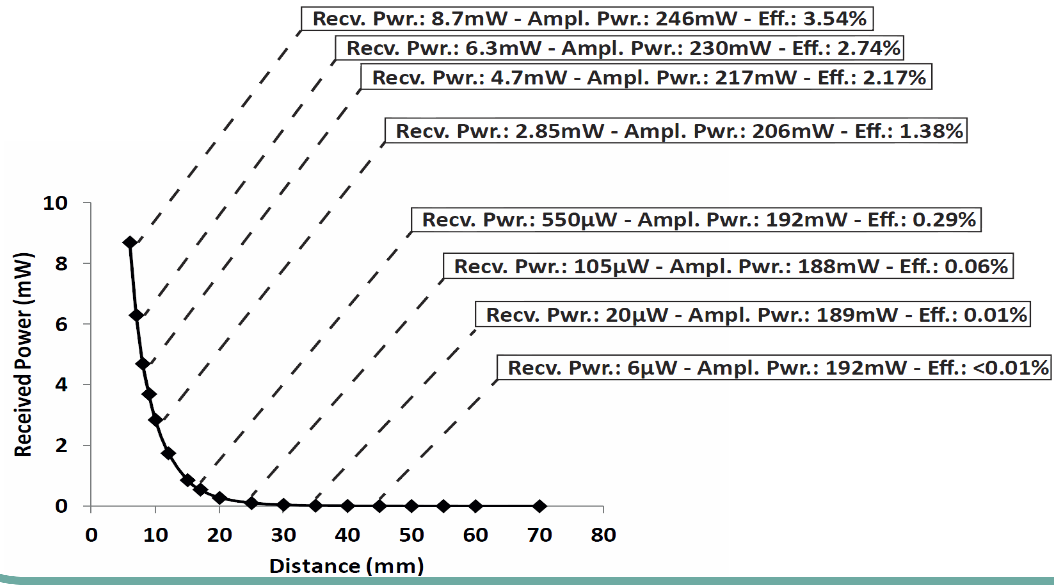




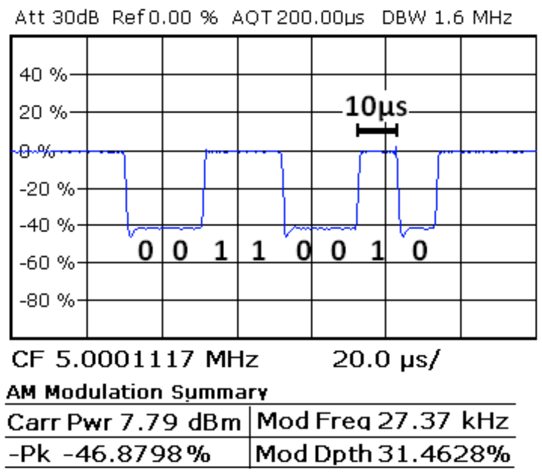


- Higher link efficiency (up to 35% higher)
- Higher voltage gain (up to one order of magnitude higher)

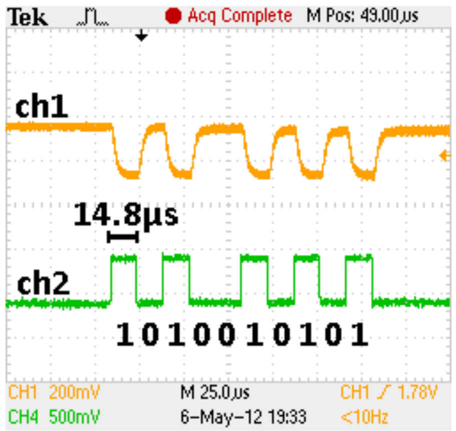
Power & Data Transmission



Power



Downlink Bitstream – 100 kbps



Uplink Bitstream – 66.6 kbps

Data

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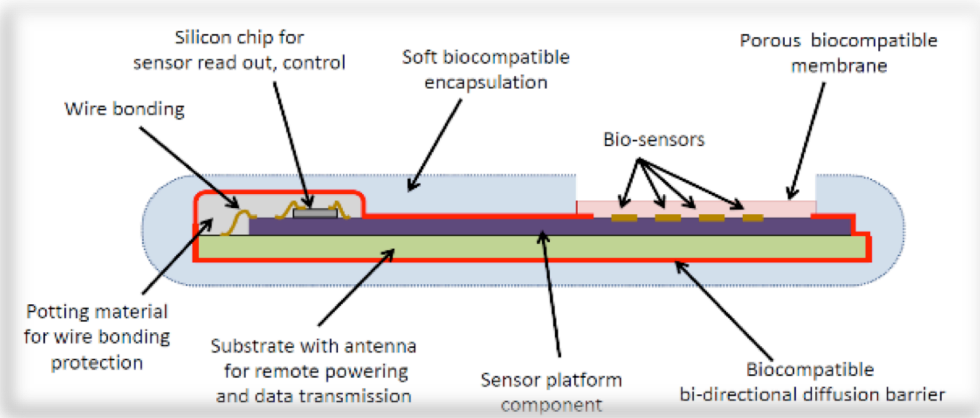
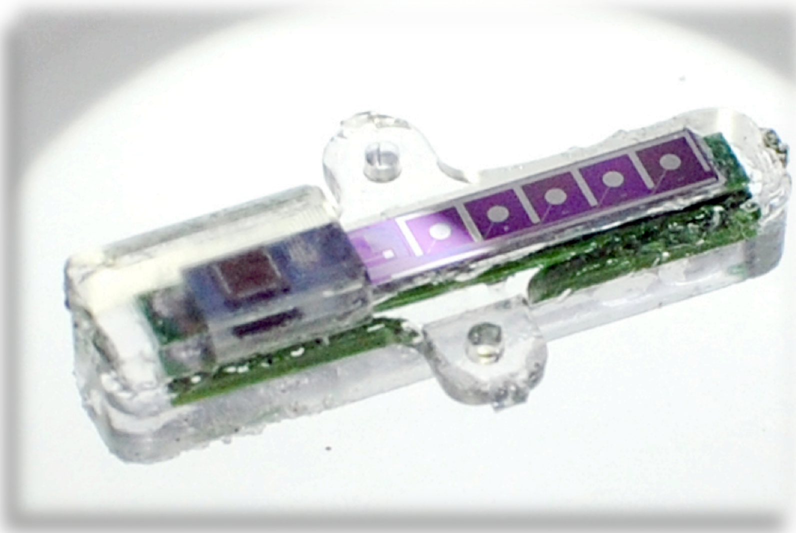
Biocompatibility





Challenges

Prevent Cu leaking (coil)

Prevent CNT diffusion (sensors)

Prevent circuit corrosion

Prevent sensors biofouling

Solutions:

Parylene C inner coating

USP class 6 Silicone external coating

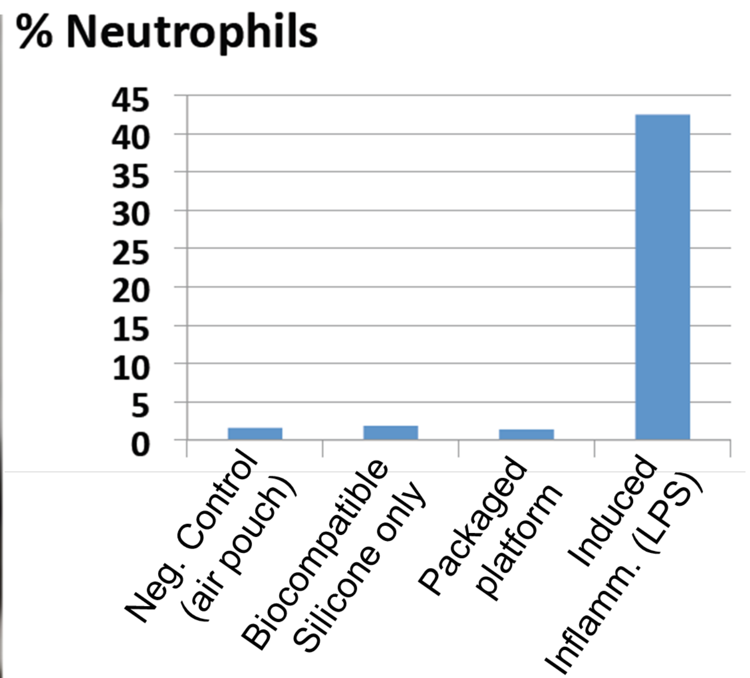
CNT entrapement in chitosan + outer membrane

Investigations:

Cytotoxicity tests

In-vivo tests

In vivo inflammation



- Subcutaneous implant in mice
- No significant inflammation after **30 days**

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Conclusions

- Continuous care of chronic patients is possible through specialized bio-electronics
- Significant improvement over the *state of the art*:
  - FDA-approved wearable glucose monitoring systems
- Electronic implants represent a near-future technology and can be more patient-friendly
- Challenges include the plurality of technologies as well as the interaction with the human body

Thank you

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- Michael Fairhead

Thank you