Semiconductor technology for new architectures of implantable devices

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SMART MEDTECH

Wednesday, November 17 | 1:45 pm - 3:55 pm

Content

Semiconductor technology for new architectures of implantable devices

- About imec
- From wearable monitoring to implantable treatment
- Semiconductor building blocks for implantable devices

imec – what we stand for

"when no one can solve your problem, we will"

#FACTS

- °1984, non profit
- Core assets
  - +4500 **R&D top talents** attracted from around the globe
  - >€3B **leading-edge semiconductor fab facilities** as a unique toolbox
  - Entry to an **ecosystem** of leading institutions & companies
- 2020 figures
  - €680M revenue
  - 161 patent applications
  - 1866 peer-reviewed publications
  - 5 spin-offs

From
wearable monitoring
to
implantable treatment

Wearable experience of imec

Foundation for implant external units

PSYCHIATRY

NEUROLOGY

RESPIRATORY

(NEPHROLOGY)

CARDIOLOGY

GYNAECOLOGY

ORTHOPEDICS

MUSCULOSKELETAL

Introducing closed loop implant program

"Artificial organs"

(Multiple) Chronic Conditions

The market and societal burden

Webpage Center for Disease Control and Prevention CDC (2021)

A costly burden

Those with MCC have more prescription, out of pocket, and total healthcare costs[8]

WITH EACH ADDITIONAL CHRONIC CONDITION:

- average medical payments **more than double**,[9] suggesting chronic conditions may interact to increase costs exponentially
- annual healthcare costs **increase 80-300%**, depending on age, sex, and chronic condition profile[10]

Amalia Adler-Waxman (2017), This is the biggest challenge to our health, World Economic Forum

Heart disease and stroke

1 in 3	$199	$131	78
DEATHS	BILLION	BILLION	MILLION
or more than 859,000 people each year	in health care system costs	in lost productivity from premature death	people with high blood pressure

Diabetes

30.3	84.1	$237	$90
MILLION	MILLION	BILLION	BILLION
Americans with diabetes	people with prediabetes	a year in medical costs	a year in lost productivity

Obesity

- Nearly 1 in 5 children are obese
- 1 in 3 adults are obese
- Obesity increases the risk for other chronic diseases like diabetes, heart disease, and some cancers

Arthritis

Arthritis Costs, Per Year

$140 Billion	$164 Billion
in direct medical costs	in indirect costs associated with lost wages

Source: Health and Economic Costs of Chronic Disease, CDC

Innovu (2021), Cost of Chronic Disease to Reach $42 Trillion by 2030

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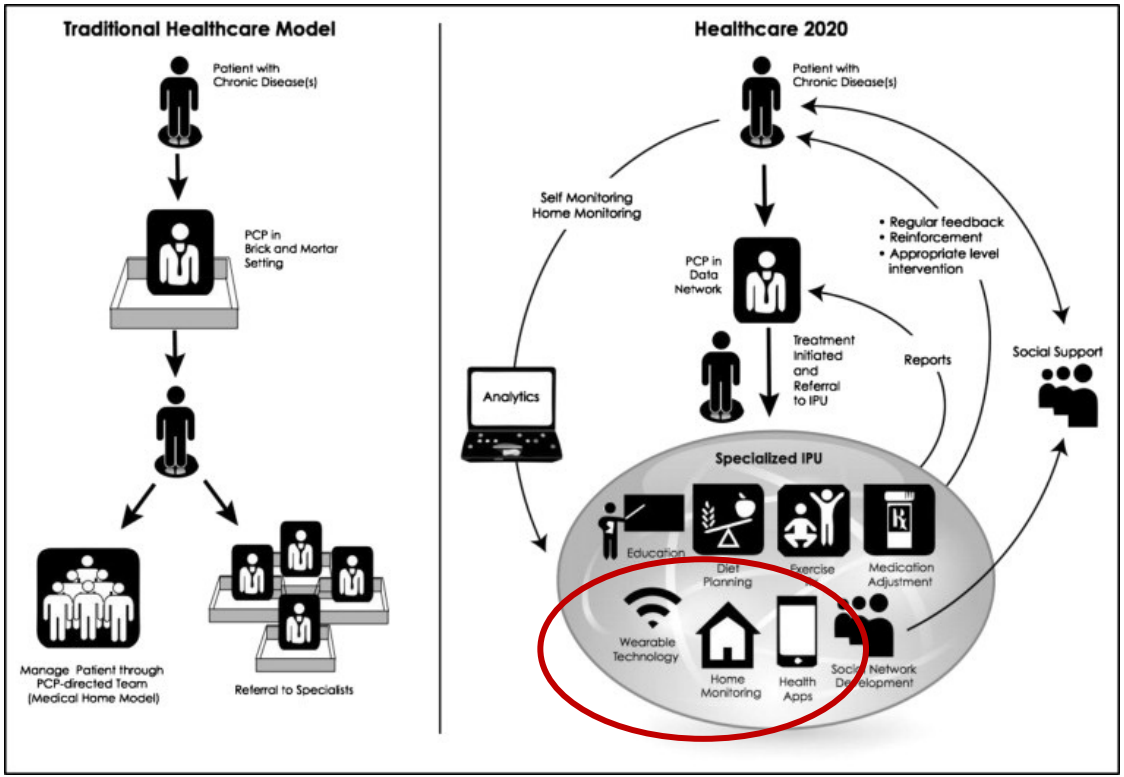
(Multiple) Chronic Conditions

Current approach



Milani, R. V., & Lavie, C. J. (2015). Health care 2020: reengineering health care delivery to combat chronic disease. *The American journal of medicine*, *128*(4), 337-343.

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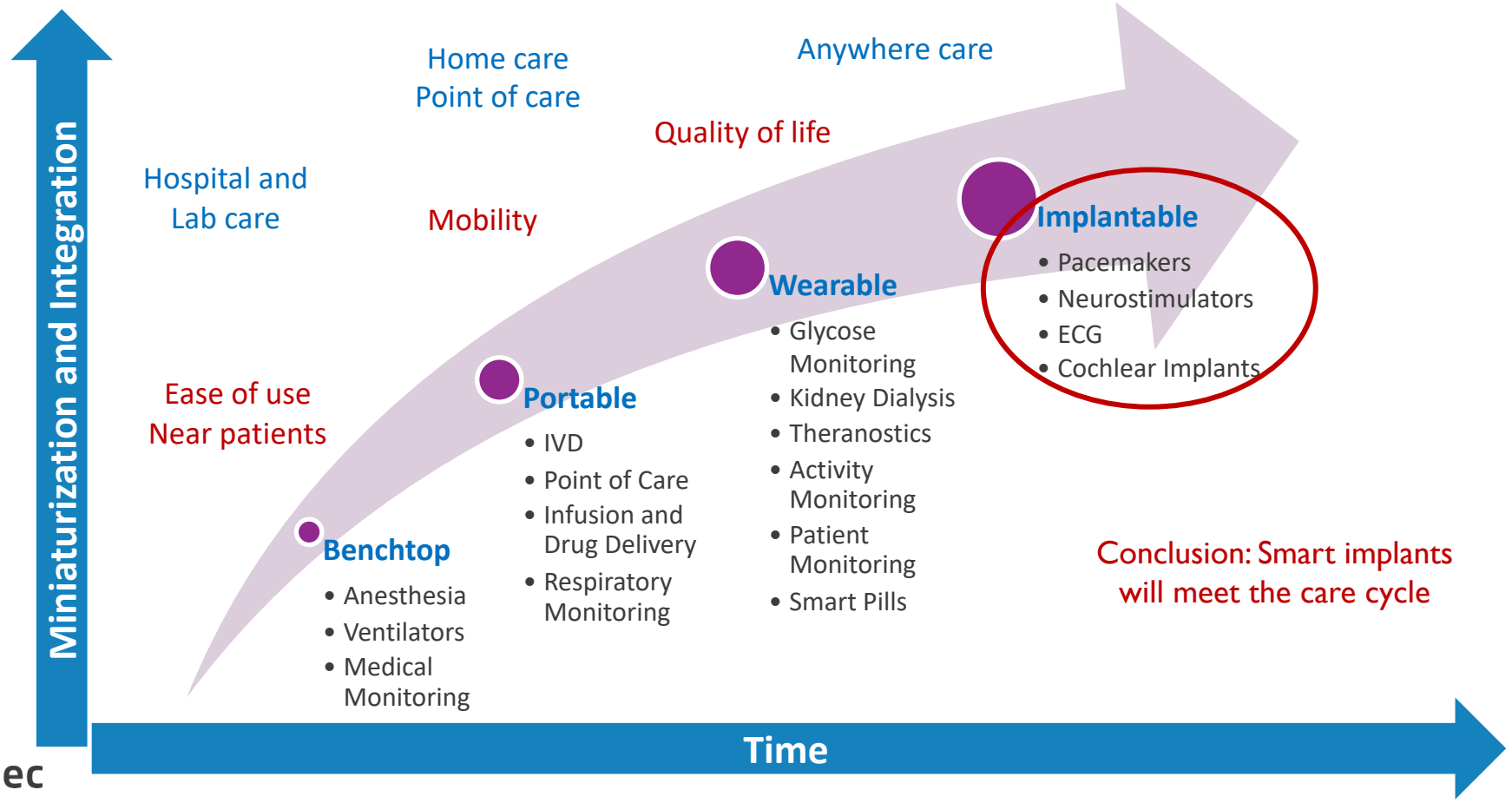
THE EVOLUTION OF MEDICAL DEVICES TOWARDS IMPLANTATION



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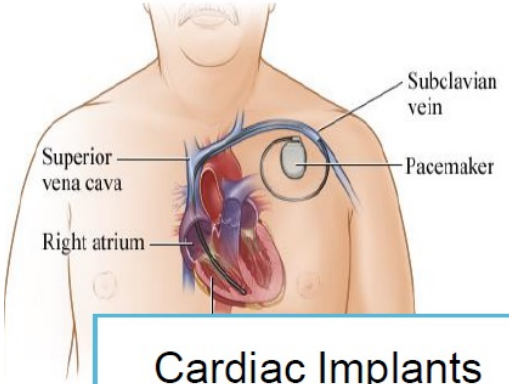
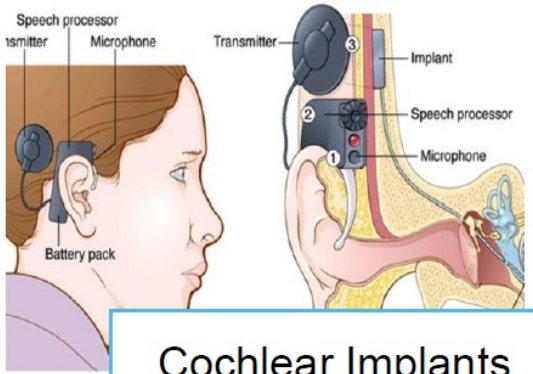
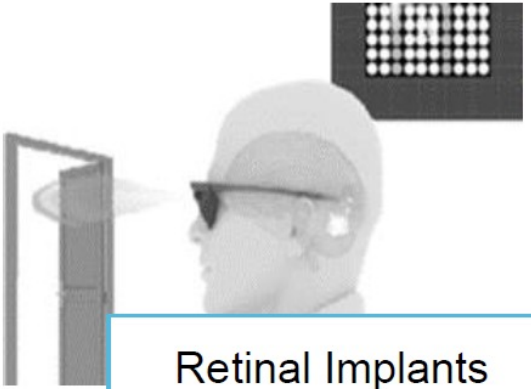
TODAY THERE ARE 6 KEY TARGETS OF ELECTRICAL STIMULATION



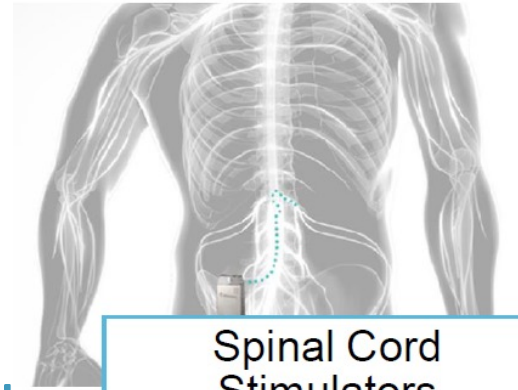
Cardiac Implants



Cochlear Implants

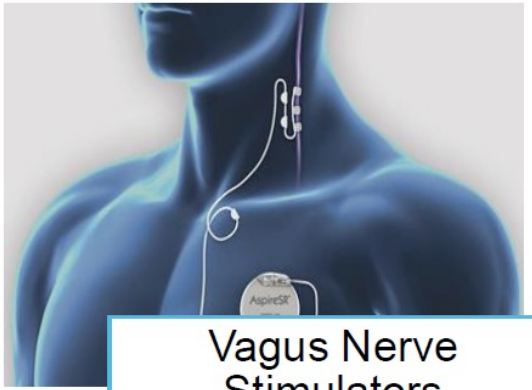


Retinal Implants



Spinal Cord Stimulators

Deep Brain Stimulators



Vagus Nerve Stimulators

IMPLANTABLE NEUROSTIMULATORS REMAIN A MAJOR APPLICATION

LivaNova

IMPLANTABLE NEUROSTIMULATOR
SENTIVA®

- for vagus nerve stimulation
- wireless programmable
- non-magnetic

VIDEO

INTRAPACE

IMPLANTABLE NEUROSTIMULATOR
ABILITI®

- for gastric stimulation

Cyberonics

IMPLANTABLE NEUROSTIMULATOR
ASPIRESR®

- for vagus nerve stimulation

VIDEO

nevro

IMPLANTABLE NEUROSTIMULATOR
SENZA®

- medullary

EnteroMedics

IMPLANTABLE NEUROSTIMULATOR
VBLOC® MAESTRO®

- for vagus nerve stimulation

VIDEO

Axonics

IMPLANTABLE NEUROSTIMULATOR
R-SNM

- sacral nerves stimulation
- wireless programmable

NUVECTRA

IMPLANTABLE NEUROSTIMULATOR
ALGOVITA® SCS

- medullary
- wireless programmable

VIDEO

inspire

IMPLANTABLE NEUROSTIMULATOR
INSPIRE™U2122

- for upper airway stimulation

VIDEO

NEUROPACE

IMPLANTABLE NEUROSTIMULATOR
RNS®

- for responsive brain stimulation

VIDEO

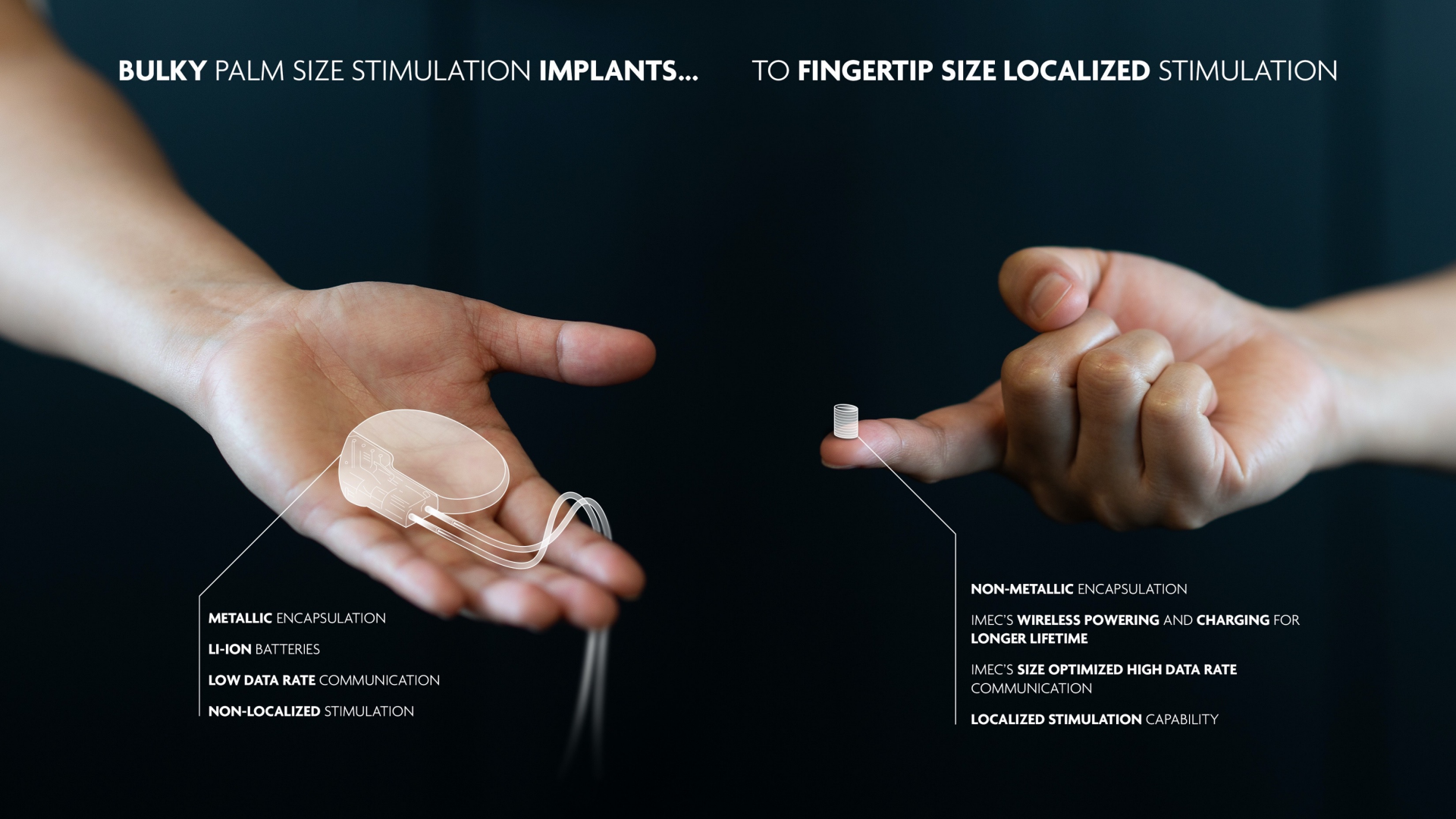
IMTHERA

IMPLANTABLE NEUROSTIMULATOR
AURA™ 6000

- for upper airway stimulation

BULKY PALM SIZE STIMULATION **IMPLANTS...**

TO **FINGERTIP SIZE LOCALIZED** STIMULATION



METALLIC ENCAPSULATION

LI-ION BATTERIES

LOW DATA RATE COMMUNICATION

NON-LOCALIZED STIMULATION

NON-METALLIC ENCAPSULATION

IMEC'S **WIRELESS POWERING** AND **CHARGING** FOR **LONGER LIFETIME**

IMEC'S **SIZE OPTIMIZED HIGH DATA RATE** COMMUNICATION

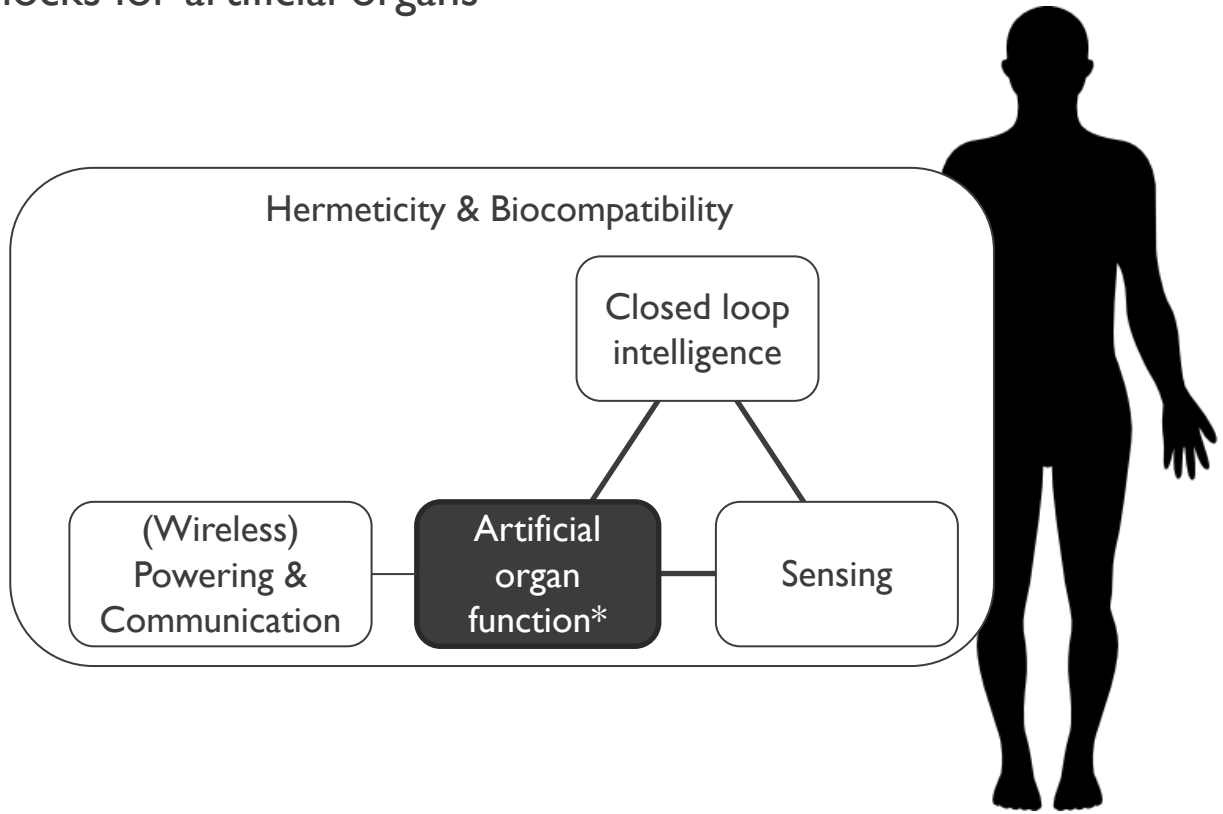
LOCALIZED STIMULATION CAPABILITY


neurogyn
imec
[NOTIFICATION CS_042 RECEIVED]
NERVE MODULATION
STARTED
[DATA PROCESSING]
WEARABLE
DATA PROCESSING AND STORAGE
SECURE COMMUNICATION WITH IMPLANT AND CLOUD DEVICE
WIRELESS CHARGING CAPABILITIES FOR IMPLANTS
PROGRAMABLE BY PHYSICIANS
[NERVE STIMULATION]
IMPLANTABLE
NERVE STIMULATION
WIRELESS POWERING
DATA PROCESSING
WIRELESS COMMUNICATION WITH THE WEARABLE

Semiconductor building blocks for implantable devices

Generic artificial implant architecture

Building blocks for artificial organs

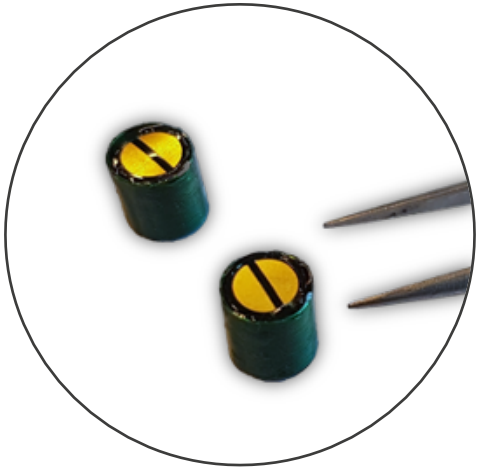


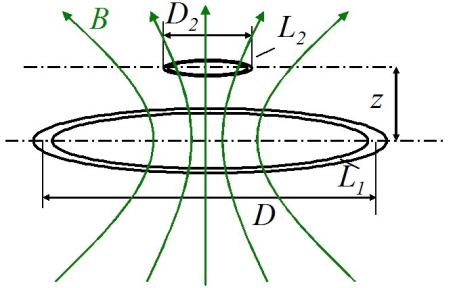
* E.g.: blood cleansing, fluid removal, mechanical function, endocrine function, nerve stimulatory function

Wireless powering

For deep implants

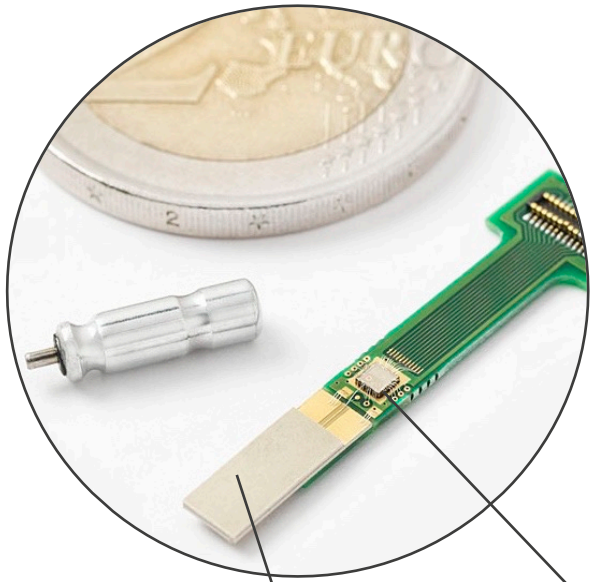
	Inductive	RF	Optical	Ultrasound
Tissue loss	✓	✗	✗	✓
TX power density safety	✓	✗	✓	✓
Reflection	✓	✗	✓	✗ / ✓
Scattering	✓	✗	✗	✗
Sensitivity to misalignment	✗	✓	✓	✓



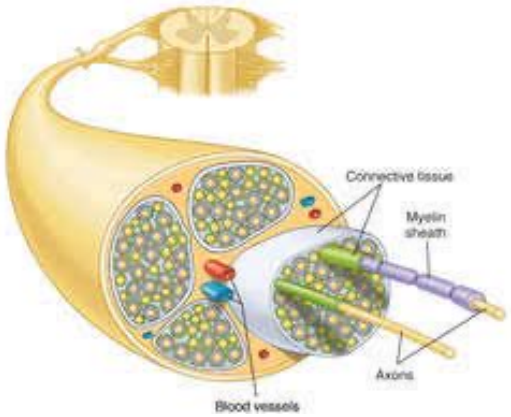


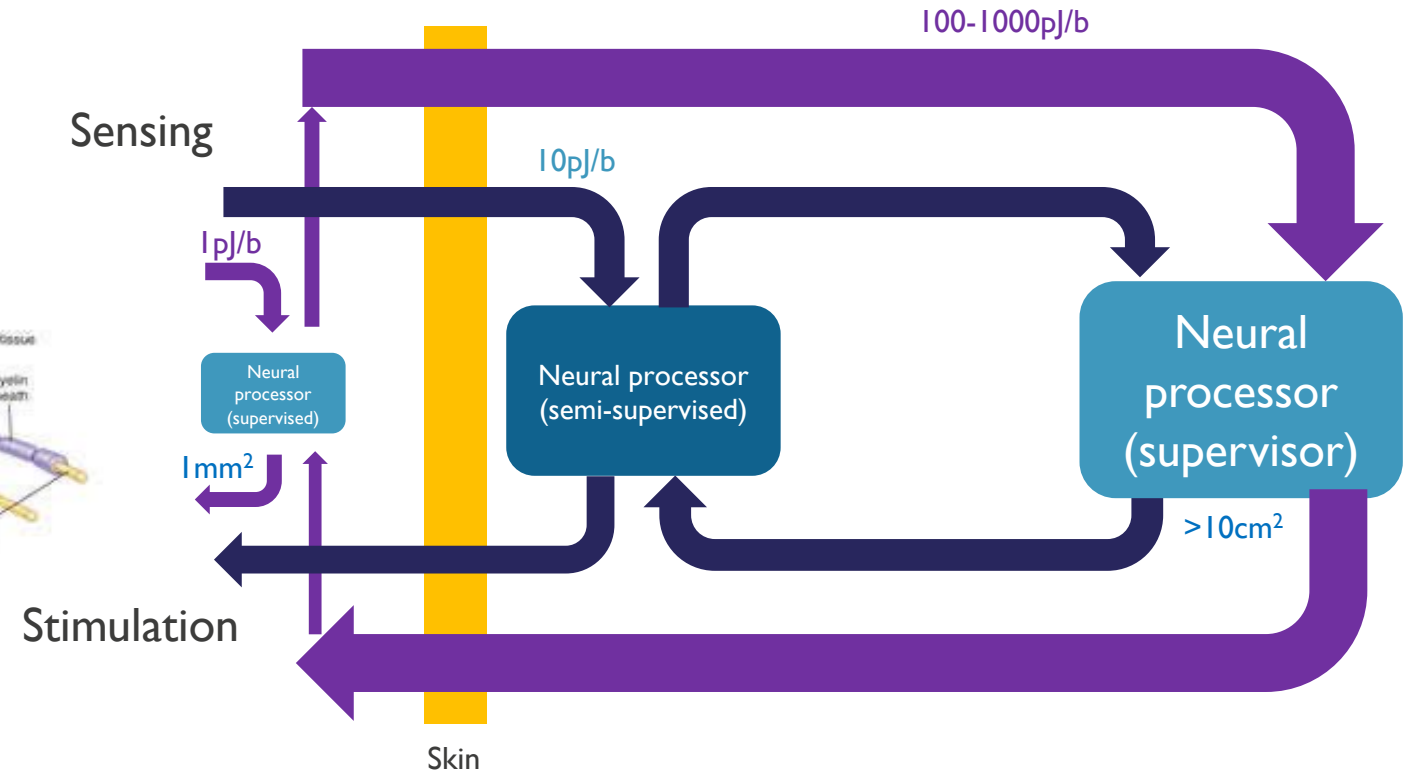
https://www.imec-int.com/implantables

Implantable wireless communication



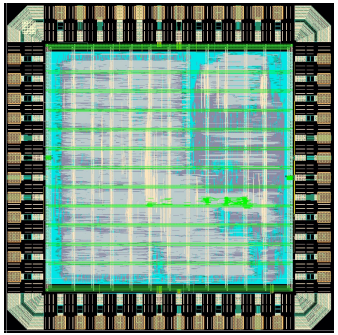
Edge computation vs. communication for PNS closing loop



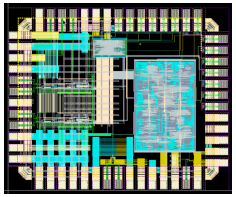


uBrain (and even smaller cousin)

Extreme edge – on-sensor – match to ULP sensors



- 336 neurons
- Digital
- Event-driven
- Small tasks (ECG, SISO uDoppler)
- 10's uW



- 100 neurons
- Integrated ASC (analog-to-spike-convertor)
- For insertables

frontiers in Neuroscience

ORIGINAL RESEARCH
published: 19 May 2021
doi: 10.3389/fnins.2021.664208

Check for updates

μBrain: An Event-Driven and Fully Synthesizable Architecture for Spiking Neural Networks

Jan Stuijt, Manolis Sifalakis, Amirreza Yousefzadeh and Federico Corradi**

Ultra-Low-Power Systems for Internet of Things (IoT), Stichting Interuniversitair Micro-Elektronica Centrum (IMEC) Nederland, Eindhoven, Netherlands

The development of brain-inspired neuromorphic computing architectures as a paradigm for Artificial Intelligence (AI) at the edge is a candidate solution that can meet strict energy and cost reduction constraints in the Internet of Things (IoT) application areas. Toward this goal, we present μBrain: the first digital yet fully event-driven without clock architecture, with co-located memory and processing capability that exploits event-based processing

A 28.2μW Neuromorphic Sensing System Featuring SNN-based Near-sensor Computation and Event-Driven Body-Channel Communication for Insertable Cardiac Monitoring

Yuming He[1], Federico Corradi[1], Chengyao Shi[1,2], Ming Ding[1], Martijn Timmermans[2], Jan Stuijt[1], Pieter Harpe[2], Ilja Ocket[3], Yao-Hong Liu[1]

[1] Imec-Netherlands, Eindhoven, Netherlands

[2] Eindhoven University of Technology, Eindhoven, Netherlands

[3] Imec, Leuven, Belgium

Abstract

This paper presents an event-driven neuromorphic sensing system capable of performing on-chip feature extraction and "send-on-delta" transmission for insertable cardiac monitoring. A background offset calibration improves the SNDR of clockless level-crossing ADCs. A fully synthesized spiking neural network extracts full ECG PQRST features with <1ms time precision. An event-driven body channel communication minimizes transmission energy. The prototype is fabricated in 40nm CMOS and consumes 28.2μW system power.

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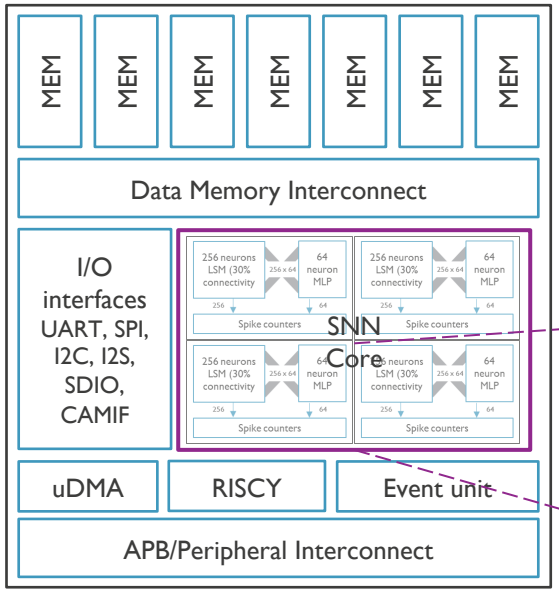
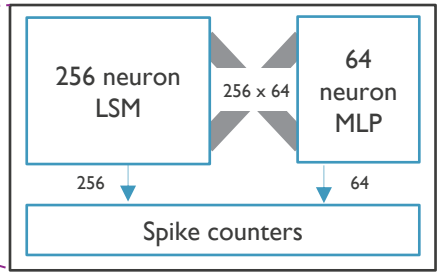
Argus

Edge IoT – highly reconfigurable with time-multiplexing – more complex applications



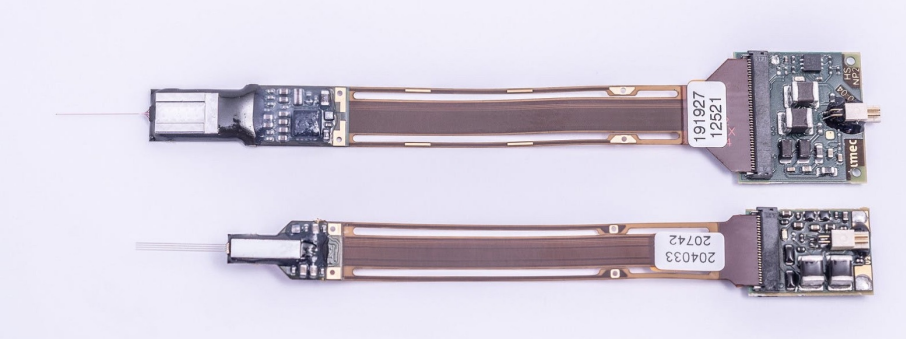


- Event-Driven Digital IP
- Instantiable into different topologies (fully synthesizable)

- Scalable multi-level interconnect & memory fabric for large SNN
- Optimized for latency x energy

Peripheral nerve stimulation

Selective stimulation

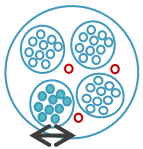


NeuroPixel 2.0 (imec Leuven)

Insertable
peripheral nerve stimulator
(imec Ghent and Leuven)

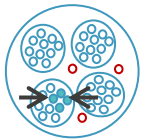
Implantable
peripheral nerve stimulator
(imec Eindhoven)

Phase 1
Specific fascicle



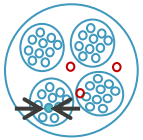
100µm

Phase 2
Specific fibres in a fascicle



10µm

Phase 3
Axon

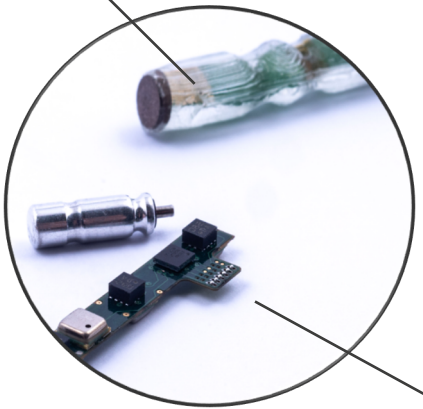


1µm

Optimum technology per phase will change!

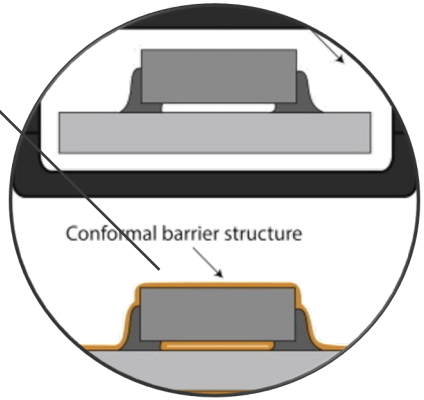
Microsystem design

System miniturization

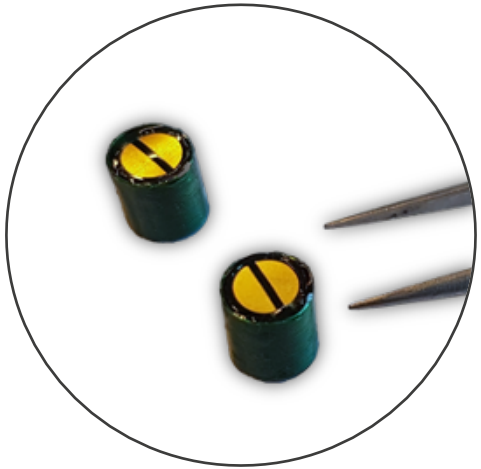


System integration

Conformal Barriers



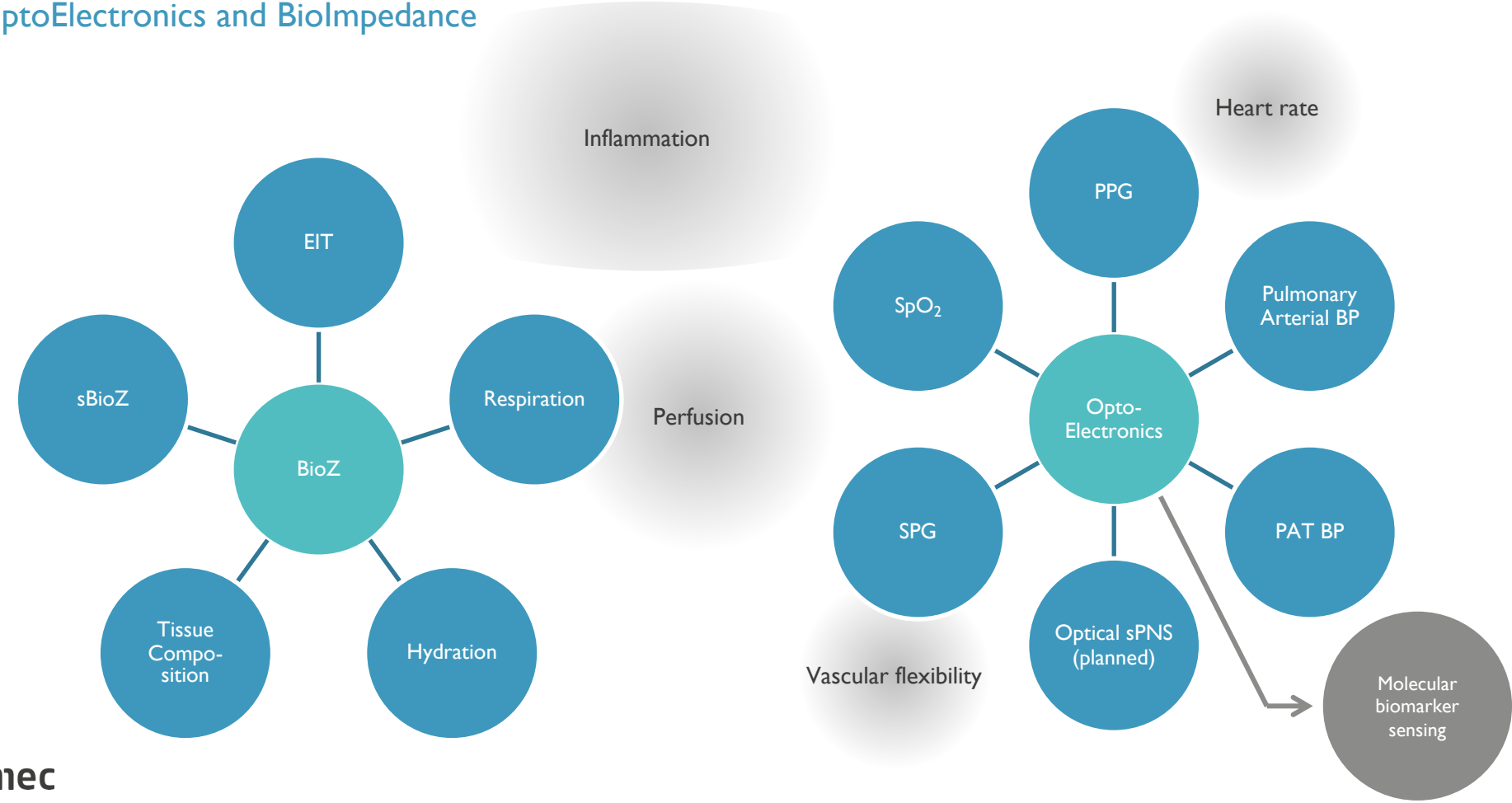
Hermetic sealing & bio compatible materials



Miniature power storage

Additional sensing for companions and implants

OptoElectronics and BioImpedance



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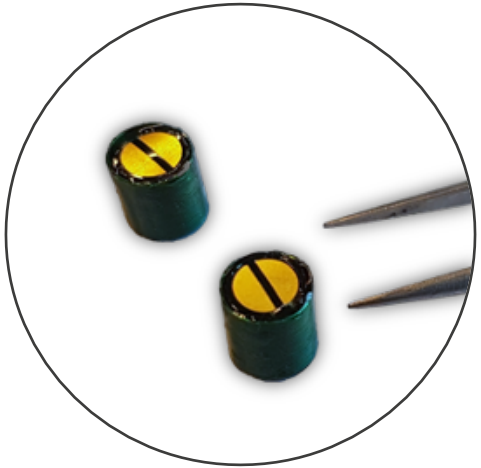
Conclusion

Conclusion

- **The societal burden of chronic diseases** requires a new approach of **closed loop implants**

- Modern semiconductor technology enables **radically different architectures** of **distributed implants**
  1. a lot of the miniaturized implantable solutions do need custom silicon
  2. each of the solutions is different than the neighbor, but it has some commonalities
  3. relationship between global pandemic and more investment in health in the next periods
  4. impact of smart health in semiconductor technology

- A **block-wise open approach** is key to develop such architectures and to **empower start-ups**



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embracing a better life