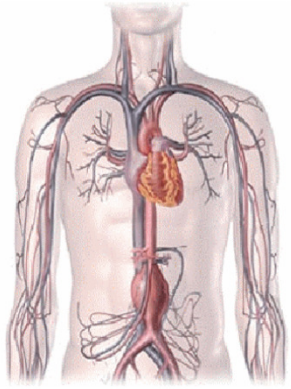
The quest for comfortable electronic implants

Robert Puers
KULeuven ESAT-MICAS

Tenants of this talk

- Main objective : improve comfort
- How small can we make them
- How to select materials
- Above all : the biocompatibility issue

A challenging *permanent* implant application

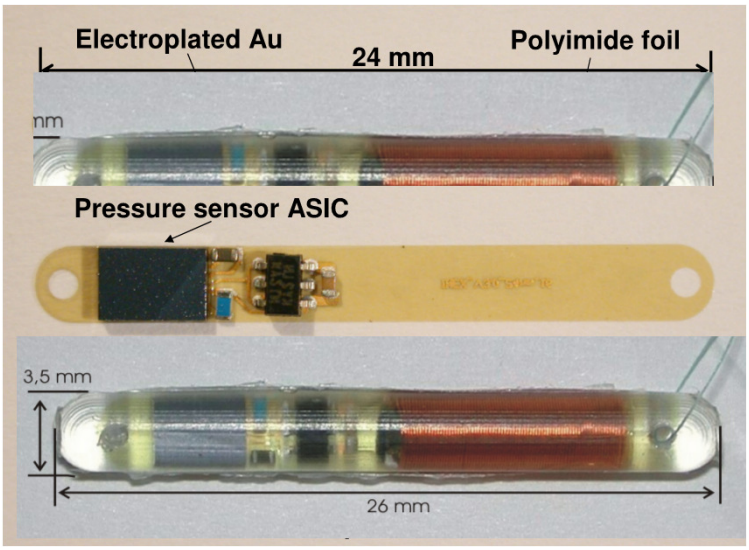


Ateriosclerosis in the aorta wall

- ~ 10 % of man population
  > 65 years with hypertension

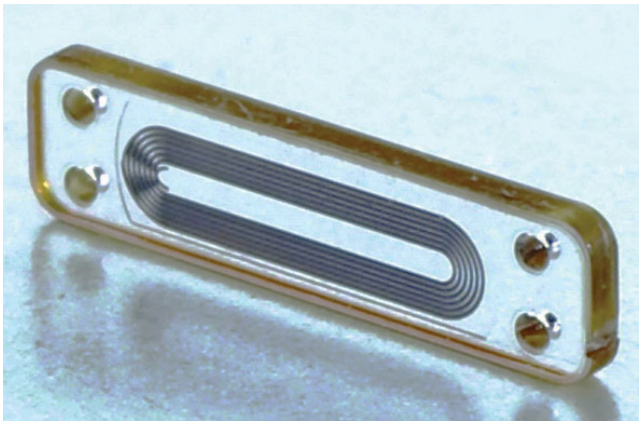
- Abdominal Aortic Aneurism (AAA)

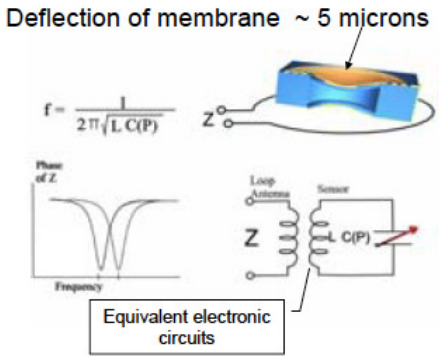
Packaged pressure monitor



RWTH AACHEN UNIVERSITY

Keep it simple ! (CardioMEMS)





- Mark Allen

Georgia Institute of Technology

Foreign materials in the bloodstream

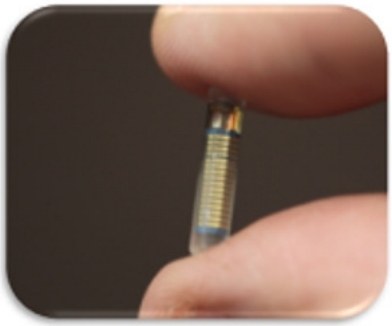
- Nature designed blood to encapsulate foreign particles
- Foreign particles will result in :
  - Trombosis and restenosis
  - Clogging of vessels
- What can be done ?
  - Medication & controlled drug release (heparin)
  - Coatings to improve hemocompatibility

Packaging : the biggest challenge

- Glass capsules / laser sealing
- PDMS or silicone rubber : mind the fluid ingress
- Parylene-C : the holy grail ?
- Importance of surface treatment
- Avoid the need of open sensors
- How flexible can we make them ?

"Bio-glass" still going strong

- Valtronic



Gerald Loeb's BION

Parylene-C is a good candidate

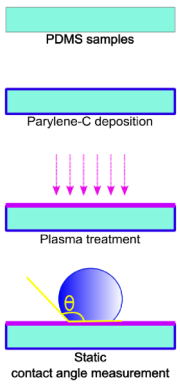
- Conformal coating (!)
- Strong hermeticity
- Wettability to be improved !
  - Better biofouling
  - Oxigen plasma treatment (low power) -> carbonyl groups
  - Followed by an SF6 plasma to create fluorinated groups

X.Bi et al.,Plasma-treated Switchable wettability on Parylene-C surface, IEEE-NEMS 2012, Kyoto, Japan, March 2012

Experimental results

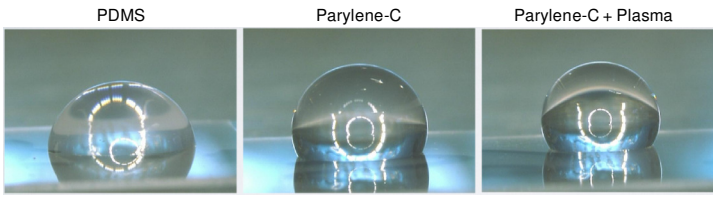
Strong Hydrophobicity

Enhanced Hemocompatibility:
- Tunes adsorption of blood proteins
- Prevents platelets adhesion and thrombus formation



Plasma treatment

Gas	Power [W]	Flow [sccm]	Time Min
O_2	100	100	10
SF_6	100	100	1



Combined effect of :

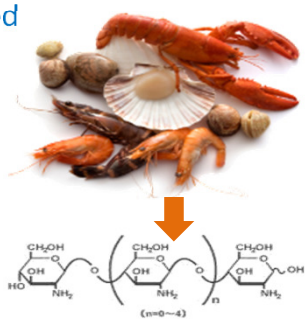
Surface roughening Fluorinated groups

Our quest : the comfortable implant

- Develop ECoG arrays largely based on *resorbable materials*
  - *Strong enough during insertion*
  - *Lower irritation during use*
- *Target use in lesion cavities*
  - *Design for high mechanical flexibility*
  - *Recording and stimulation for therapy*

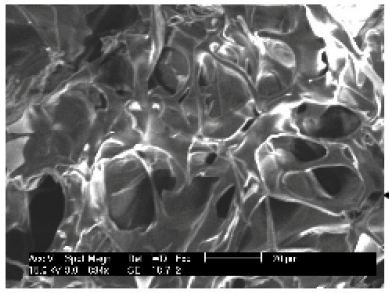
Material selection

- Non-resorbable backbone:
  - Pt electrodes and connectors, PI or parylene C insulation
  - Classical materials, but very thin and finely patterned



- Resorbable materal: Chitosan
  - It can be dissolved in an acidic environment, facilitating spin-on processing
  - Good adhesion
  - Has haemostatic and antiseptic properties
  - Can be formed into a porous, fast resorbable form
  - Degradation rate can be varied by altering the degree of deacetylation

Fabrication

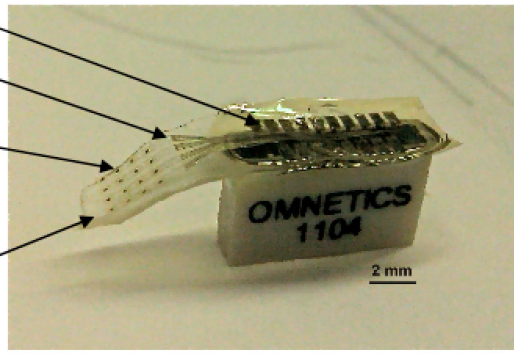


Bondpaths for connector

Insulated microwires (width > 10 µm)

Electrodes (ø 92 µm)

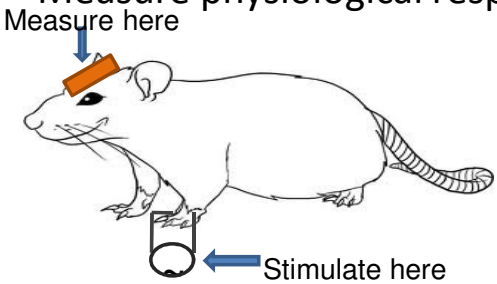
Sheet of porous chitosan

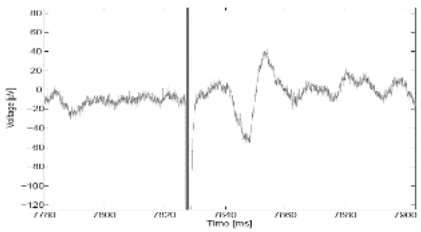


In vivo testing

- Implantation on meninges -> or under meninges in rats

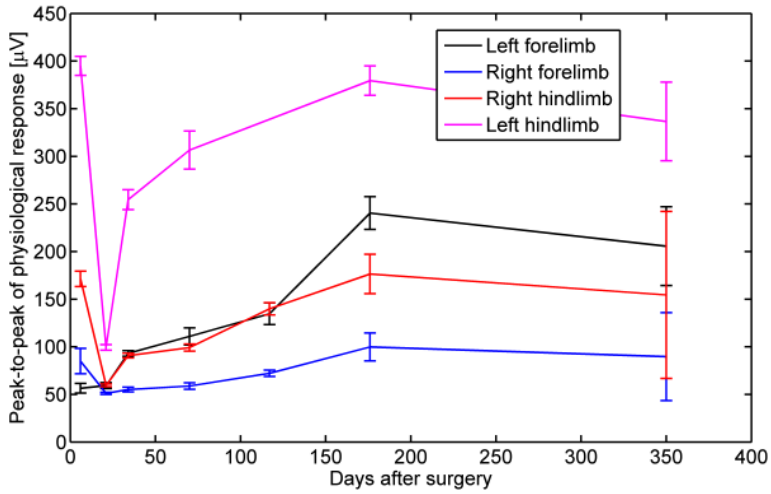
- Measure physiological response



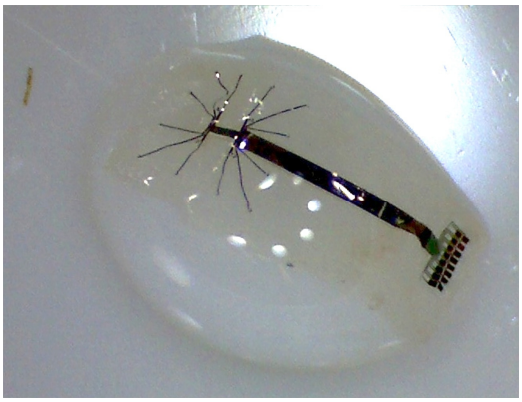


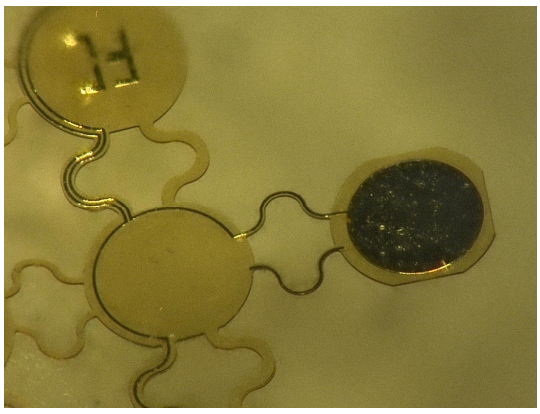
Typical measurement of stimulus and physiological response

Amplitude of response over time



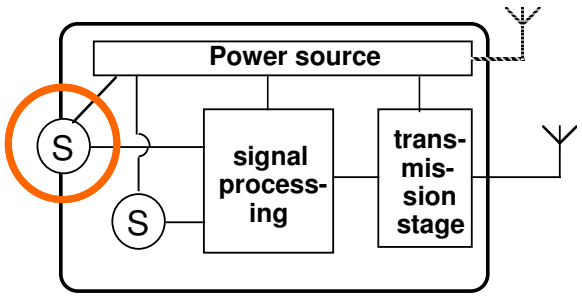
What is next : Flexible spider structures



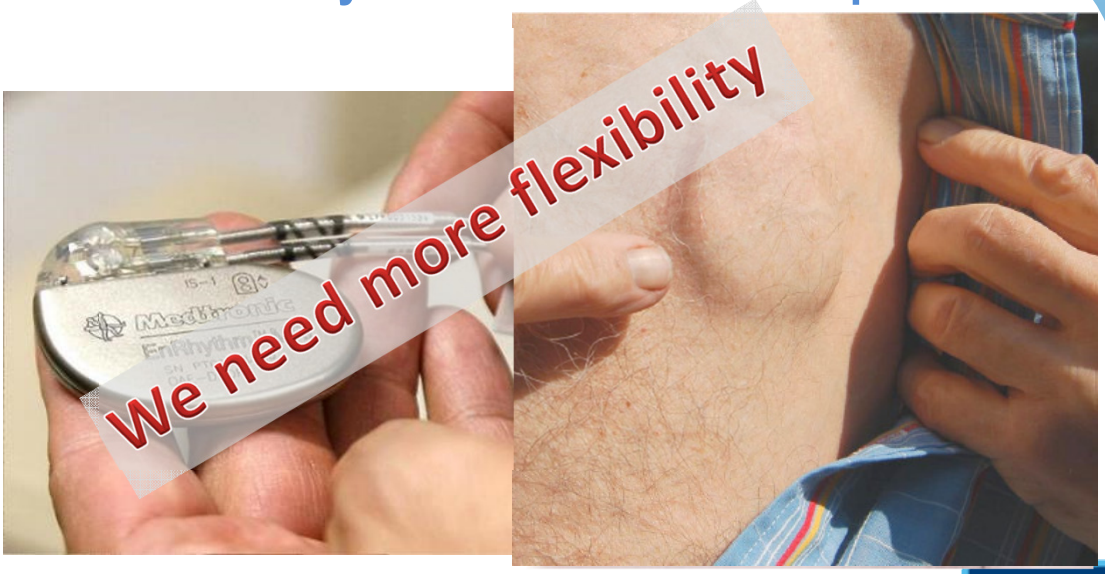


Sensing in permanent implantable devices

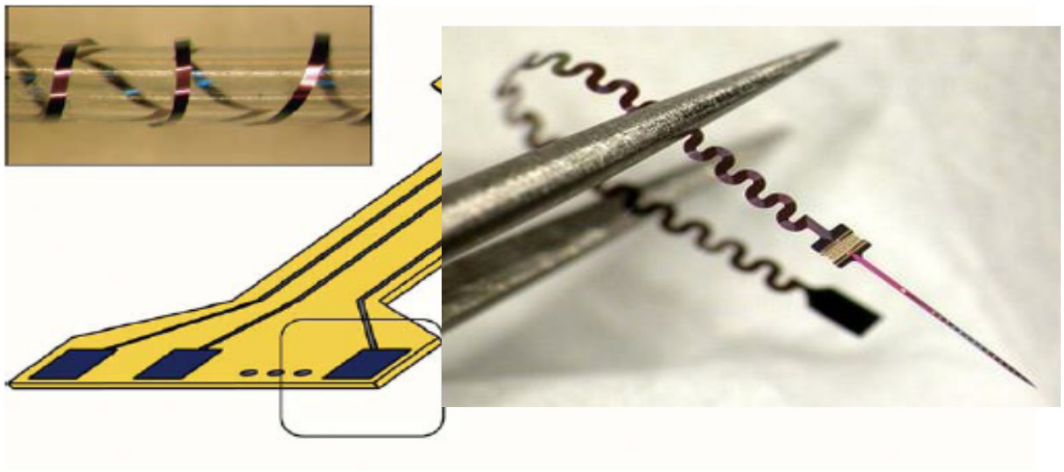
- Monitoring function :
  - built-in sensor
  - ‘open’ sensor
- Power source
  - battery
  - wireless induction
- Wireless communication
- Intelligent processing
- Biocompatible cage



Probably the best known example

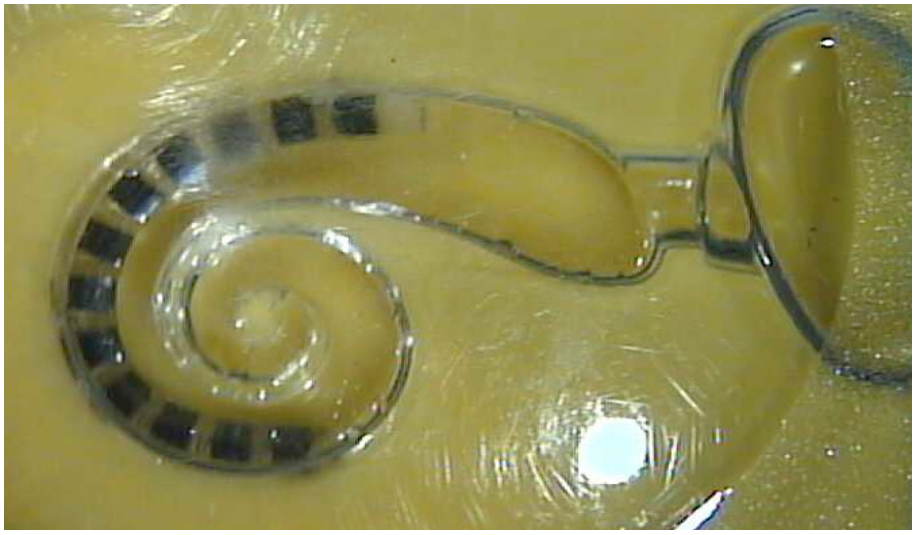


Flexibility : is silicon still in ?



The University of Michigan, Ann Arbor

More on flexibility: KULeuven electrode



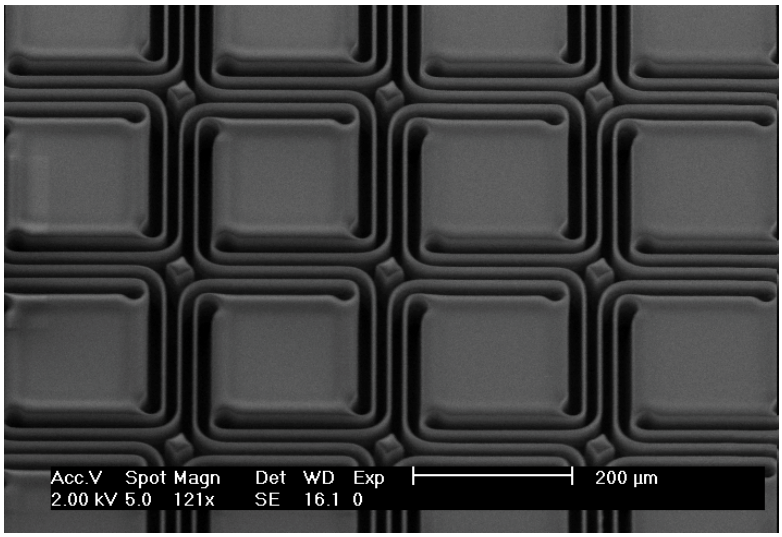
More on flexibility of silicon...

Dinyari, et al., *IEDM* 2009

KU LEUVEN

Our continuation on this idea

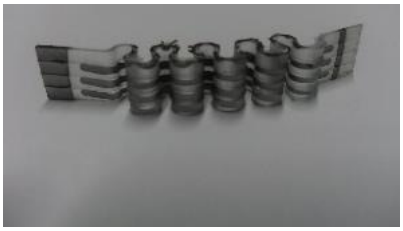
- DRIE process
- + CMOS (!)

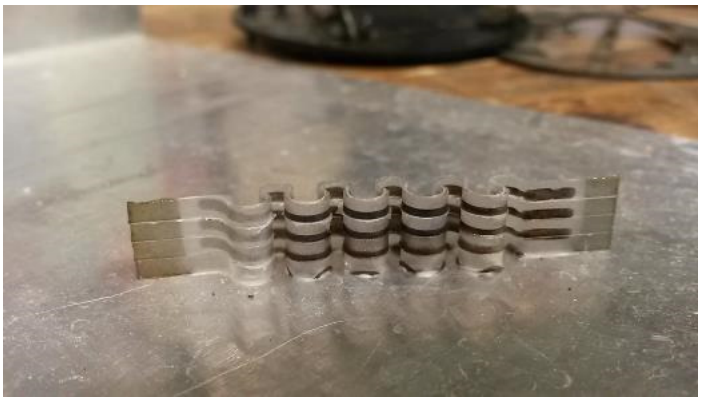


KU LEUVEN

New ways to make stetchable connections

- Gold sputtered with Ti pre-sputtering and plasma pre-treatment

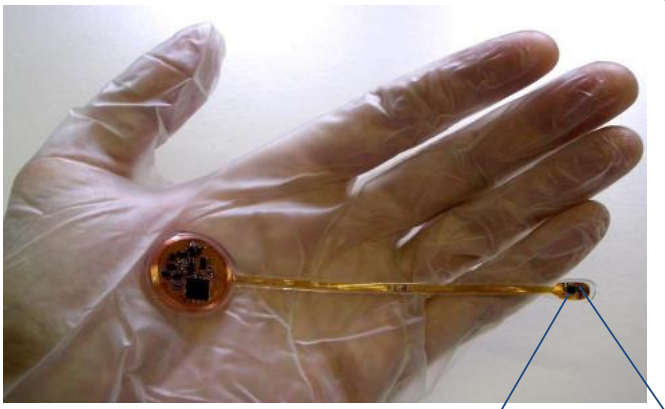




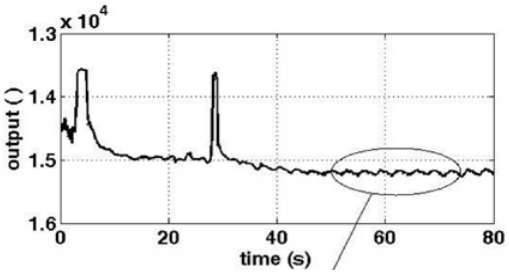
Permanent pressure monitoring

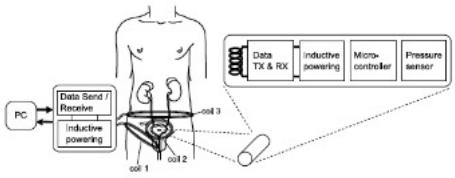
- capacitive sensing
- introducing flex
- separate circuit
- inductive powering

- linking with stimulator
- towards the ultimate urologic pacemaker

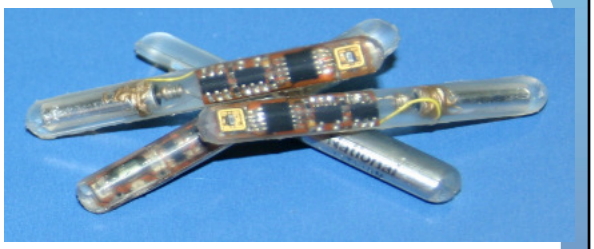


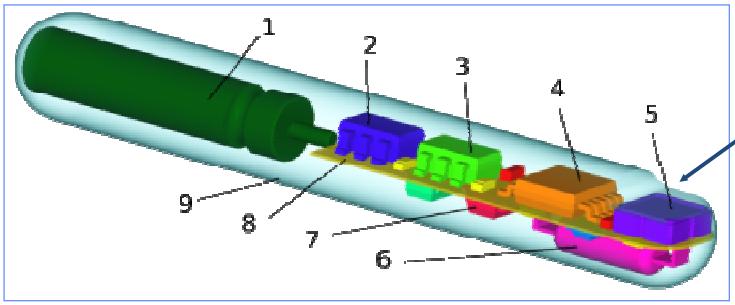
Interesting phenomena observed





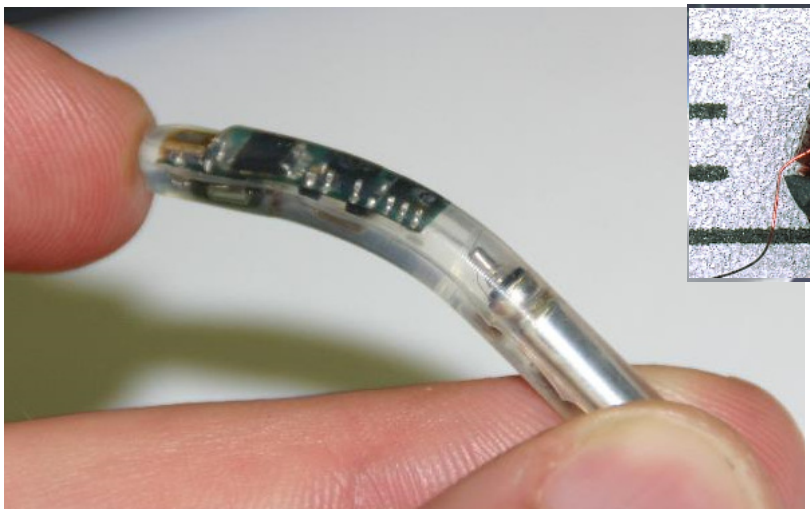
Bladder pressure diagnosis

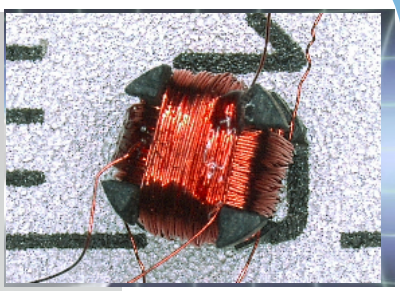




Capacitive pressure sensor

Extreme miniaturization of the 3D inductive link

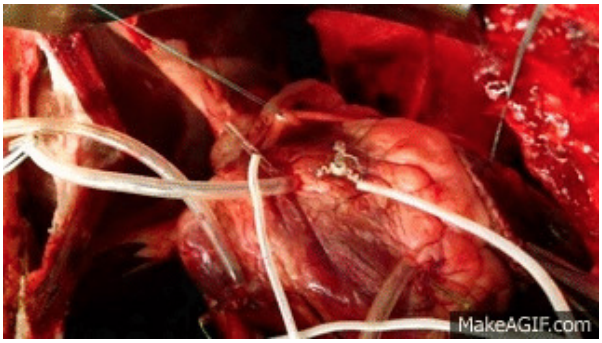


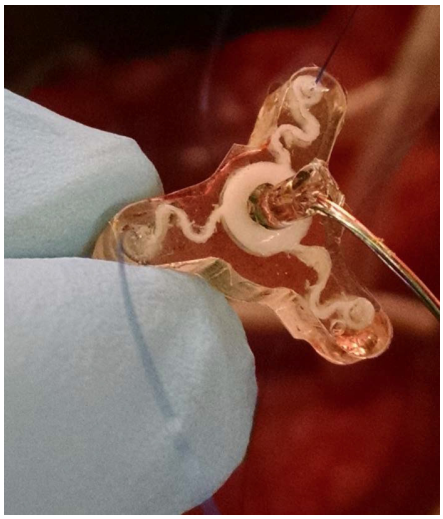


- 15mm^3
- 1 mW

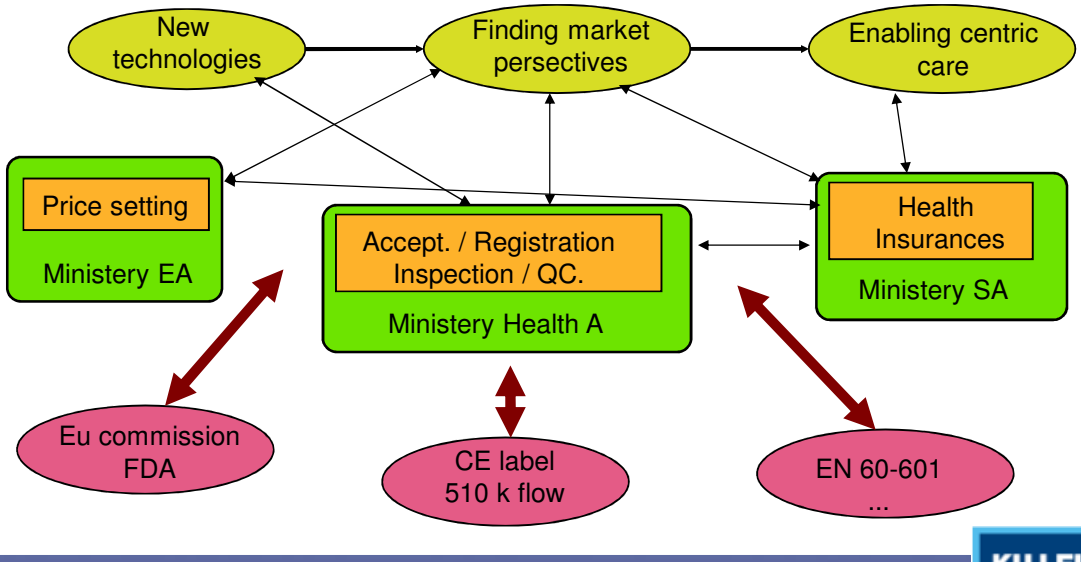
Contractility of the heart

- Sensor on heart wall
- Bosch BMA280 accelerometer





Then finally, introduction in market…



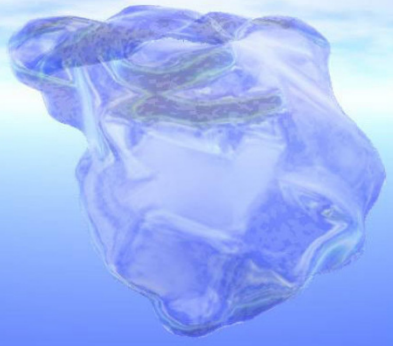
Lessons learned

- Flexibility is key
- Be modest : avoid complexity
- Avoid 'open' sensors

- There is a tremendous opportunity for MEMS
- Learn from nature
- Be modest in predictions : it takes a long road to implementation in society !

My dream

Anne Marie Cernoch's artist impression : "Electro-Gelly"



KU LEUVEN

Thank you !

KU LEUVEN