STRETCHABLE ELECTRONICS APPLIED IN TEXTILE INTEGRATION

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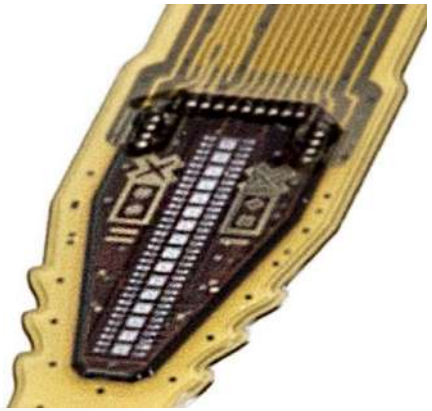
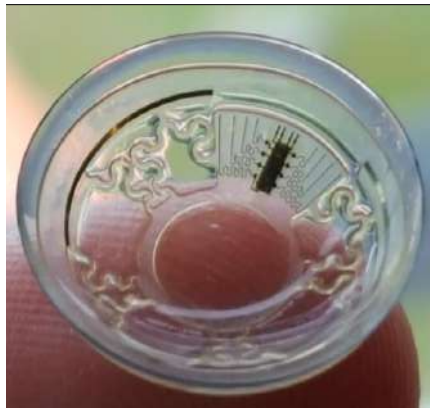
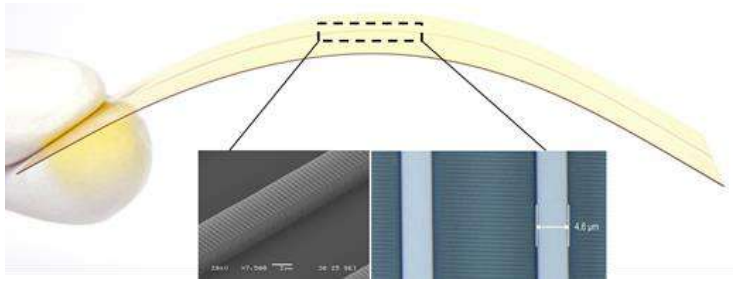
PUBLIC

IMEC - CMST
RESEARCH TOPICS

- CMST is designing and developing microsystems such as implantable devices, smart contact lenses, optical sensors and devices for IoT
- Developing technology platforms such as
  - flexible and stretchable electronics
  - opto-electronic packaging
  - polymer waveguides
  - liquid crystal technology
  - microfluidics
  - thin chip packaging







- Bringing together expertise from electronics, mechanics, physics and chemistry
- Fundamental research projects and funded collaborative projects

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CONTENTS

- Intro E-Textiles
- Stretchable electronics as a way to achieve conformability
- Architecture we're focusing on and its building blocks
- Research on washability
- Use cases
- Conclusions

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INTRO E-TEXTILES
WHAT?

- **E-textiles** = combination of **electronics** and **textiles** to form **"smart" textile products**.
- We are in contact with textiles for up to 98% of our lives, and they are starting to become intelligent.
- The ideas for e-textiles have been around for decades, but with increasing commercial focus in the last 30 years.
- Today, e-textiles remains a fragmented sector in relative commercial infancy.
- Many industry players throughout the value chain are lining up to offer the next generation of smart textile products.
- From clothing to bandages, bed linen to industrial fabrics, new products are appearing throughout a variety of verticals as this technology area is increasingly explored.

(Source IDTechEx)

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INTRO E-TEXTILES
WHAT?

Features of e-textile

- Sensing
- Actuating
- Powering
- Data processing
- Communicating
- Interconnecting

E-Textile Garments

Technical textiles

This needs integration of electronics, while **preserving** the original textile properties.

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INTRO E-TEXTILES
APPLICATIONS

- The proposed markets for e-textile products are very broad.
- In the report of IDTechEx "E-Textiles 2019-2029: Technologies, Markets and Players" the following key market sectors and product types are listed:
  - Key market sectors:
    - Medical & healthcare
    - Sports & fitness
    - Military & space
    - Enterprise, PPE & other workwear
    - Fashion
    - Heated clothing
    - Home e-textiles
  - Some specific product types:
    - Animal wearables
    - Automotive interiors
    - Motion capture
    - Haptic suits
    - Assistive clothing
- Each area has a unique mix of requirements, drivers and relevant industry players, so it is critical to understand the detail of the dynamics in each space in order to successfully plan and grow with this industry.

(Source IDTechEx)

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INTRO E-TEXTILES

E-TEXTILES @ IMEC-CMST

- Focus on development of packaging technologies
  to realize electronic circuits compatible with properties of textiles

- Investigate reliability of these systems

- Realization of prototypes in different projects

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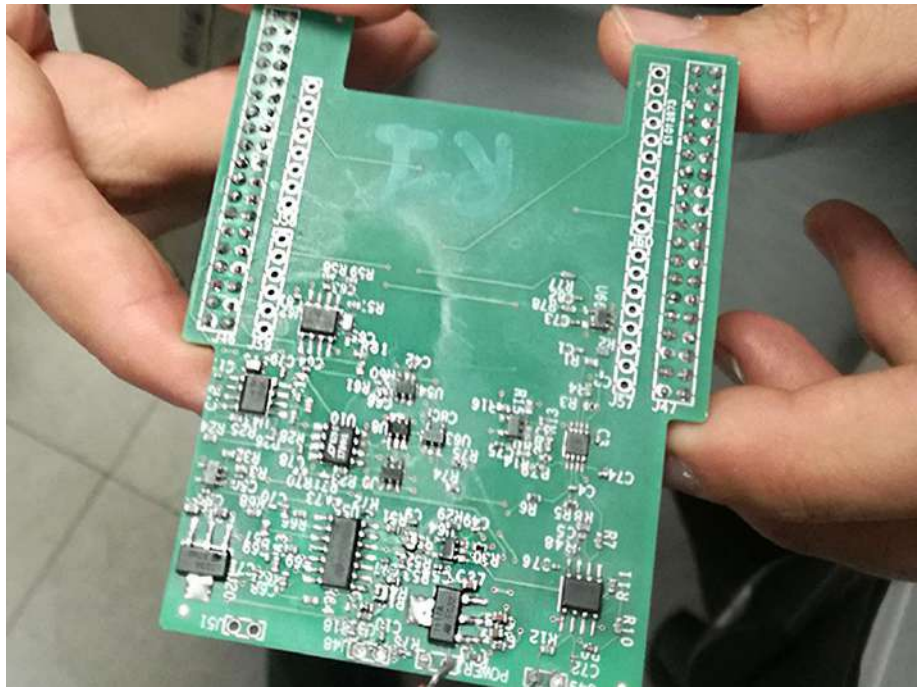
STRETCHABLE ELECTRONICS
RIGID ELECTRONICS

- Traditional electronics are rigid and not very comformable → not suitable for integration



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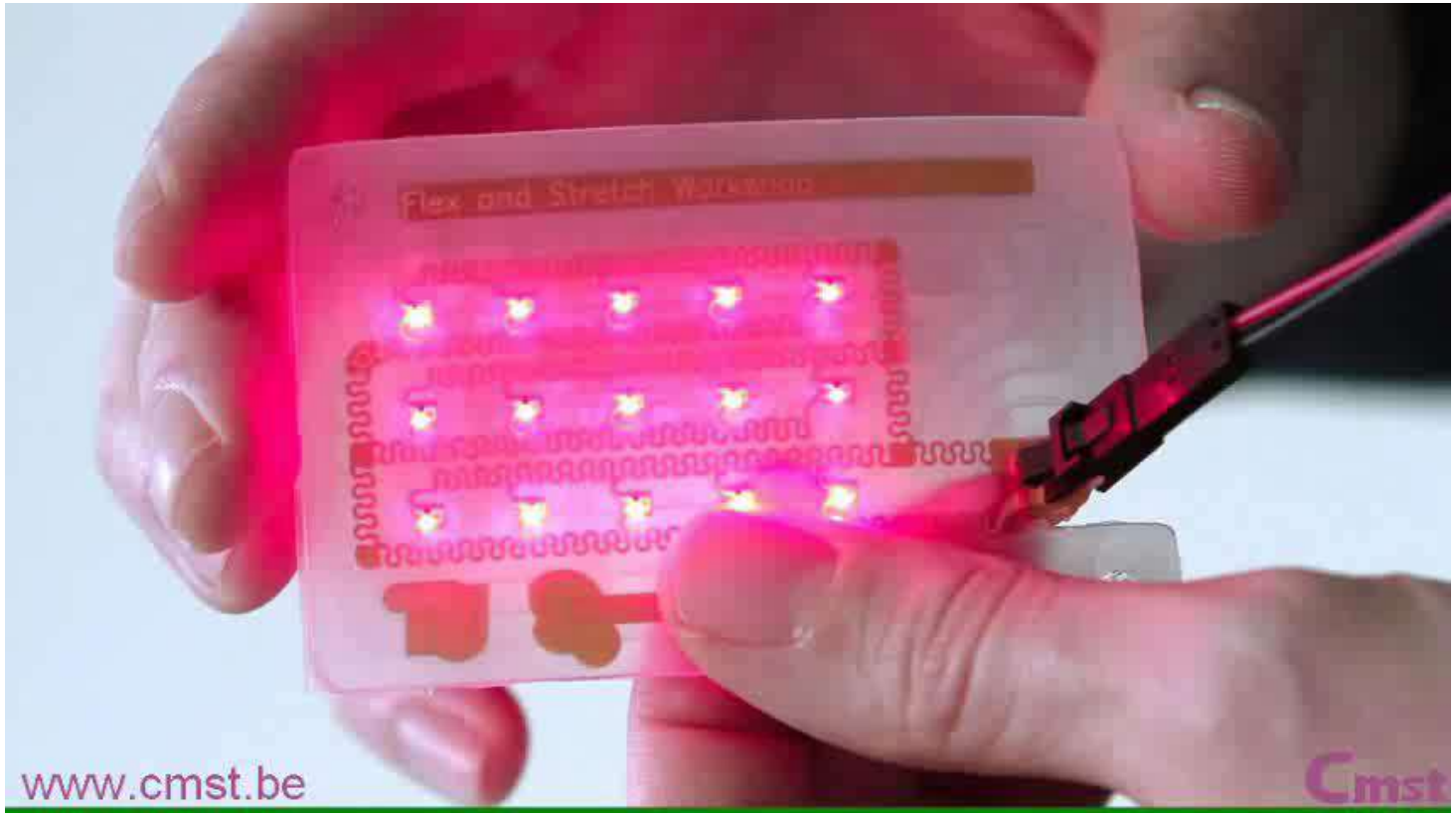
STRETCHABLE ELECTRONICS
CONFORMABILITY

- Our developed platform for stretchable electronics offers the needed conformability



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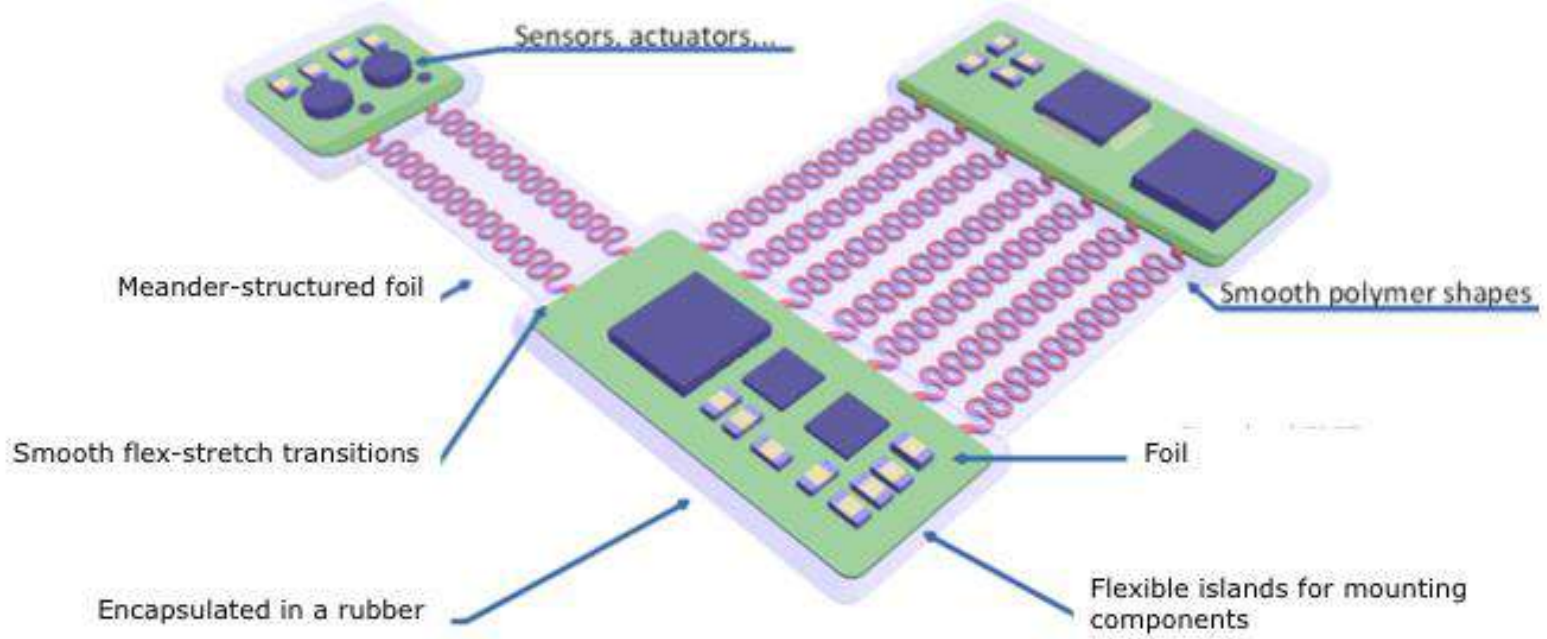
STRETCHABLE ELECTRONICS
WHAT?

- Stretchable electronic devices consist of **functional islands**, interconnected with **meander-shaped stretchable circuitry**, embedded in a **stretchable polymer**



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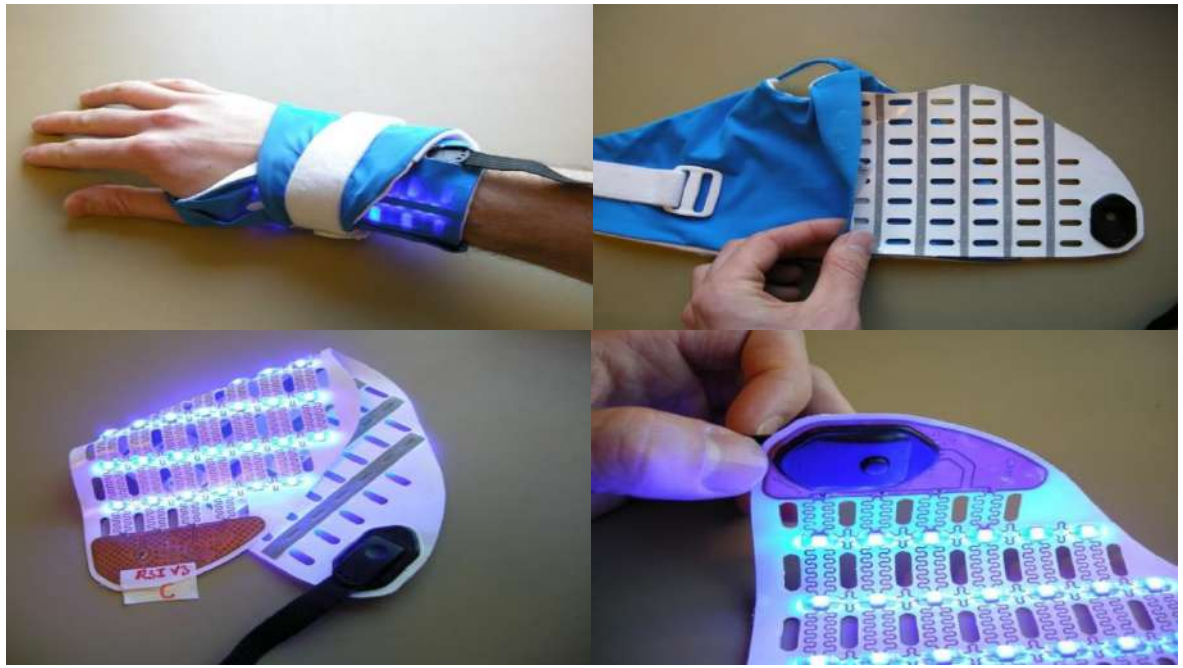
STRETCHABLE ELECTRONICS

AN EXAMPLE: CONFORMABLE WRIST-BASED PHOTOTHERAPY DEVICE

- Phototherapy: using light for relieve of pain
- Fully integrated (LEDs, passives,…) on foil
- Highly conformable to the hand by using stretchable electronics technology
- Embedded in silicone for wear comfort and washability



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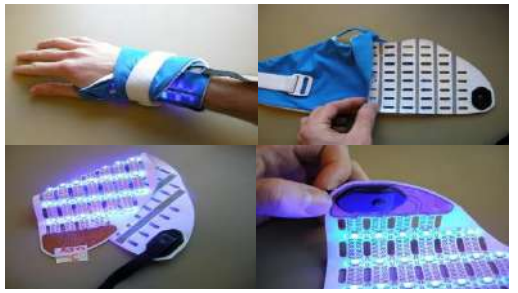
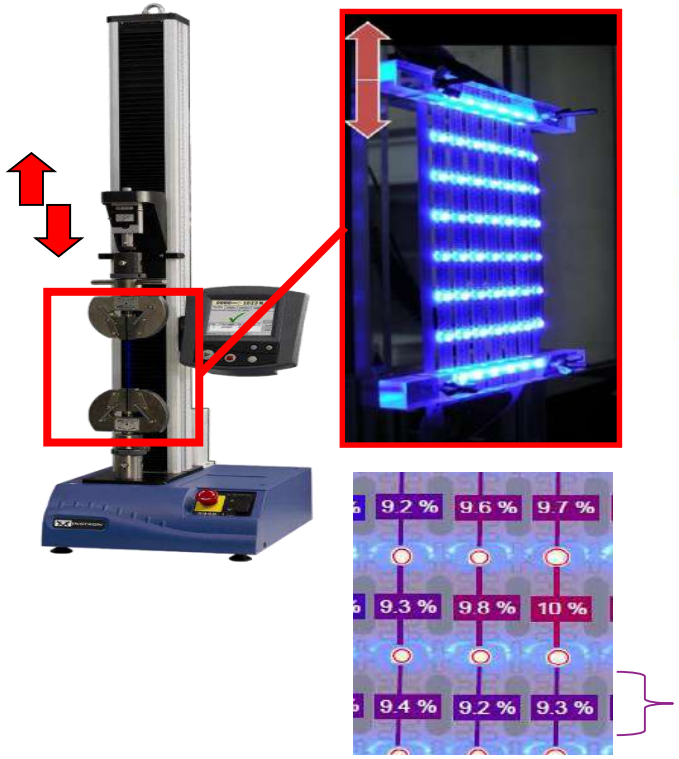
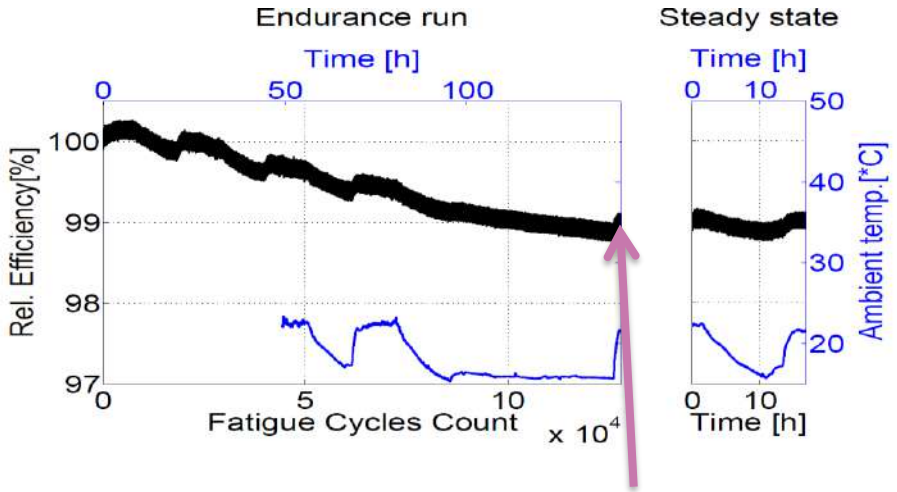
STRETCHABLE ELECTRONICS

AN EXAMPLE: PHOTOTHERAPY DEVICE - MECHANICAL INTEGRITY



- ~10% interconnect strain
- No failure after 120k cycles
- 1% efficiency loss





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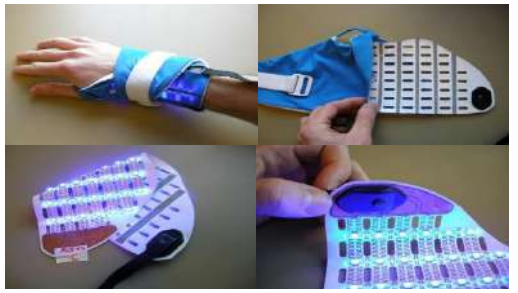
STRETCHABLE ELECTRONICS

AN EXAMPLE: PHOTOTHERAPY DEVICE - BREATHABILITY



Model consisting of wet thermo-regulated surfaces

RSI wrap device

Heat transfer due to water vapor transport

Test derived from EN31092, performed at Centexbel

Device state	Water Vapor Resistance [m^2Pa/W]
LEDs OFF	4
LEDs ON	4.7

Very high breathability ≥ Underwear

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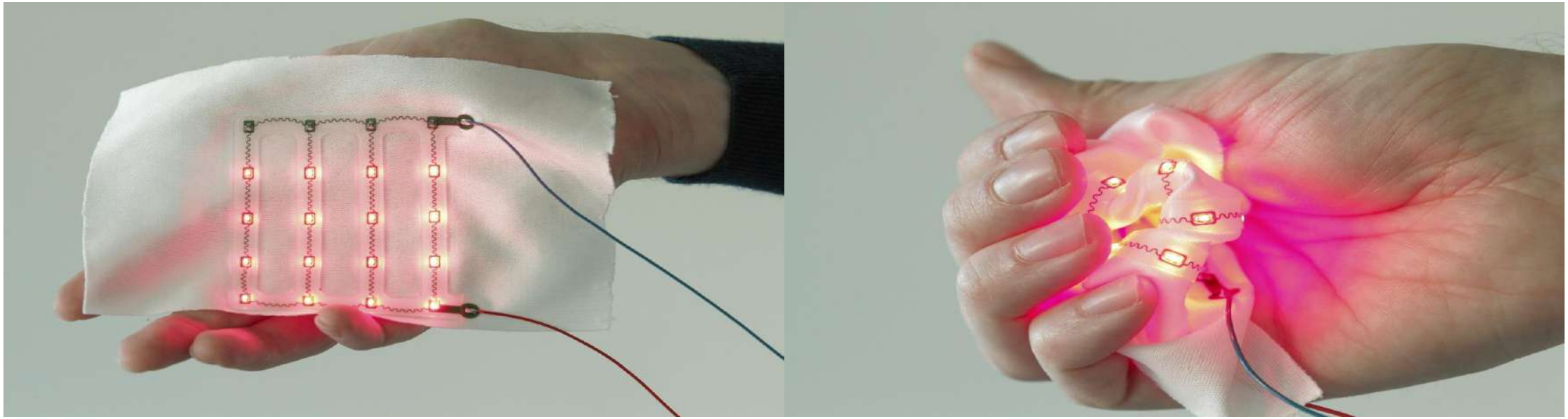
STRETCHABLE ELECTRONICS
TEXTILE INTEGRATION

- Stretchable electronics are used as base for integration of electronics in textiles



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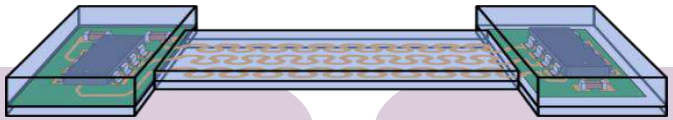
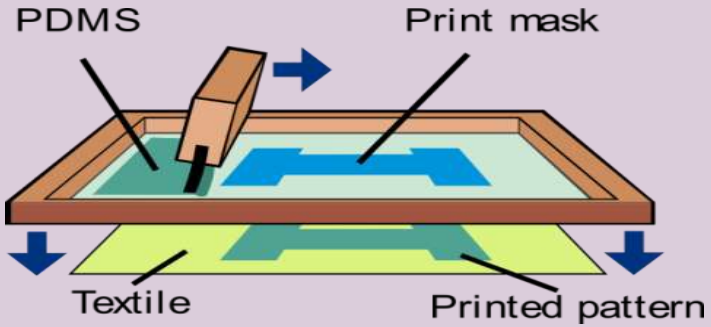
STRETCHABLE ELECTRONICS

TEXTILE INTEGRATION METHOD

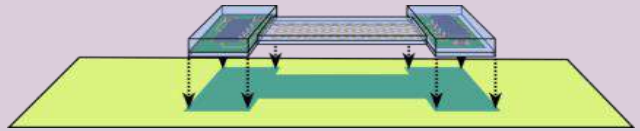
Stretchable module



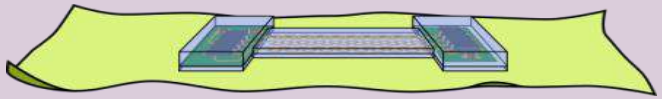
Modules with PDMS encapsulation



1) Print



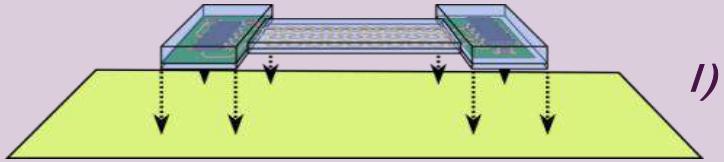
2) Place



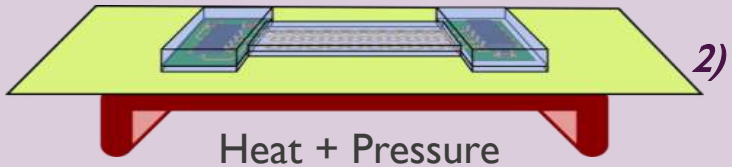
3) Cure

Process based on the screen printing of a glue layer

Modules with Thermoplastic encapsulation (e.g. PU)

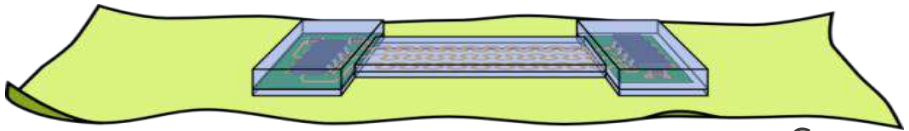


1) Place



2) Laminate

Process based on lamination



Module on textile

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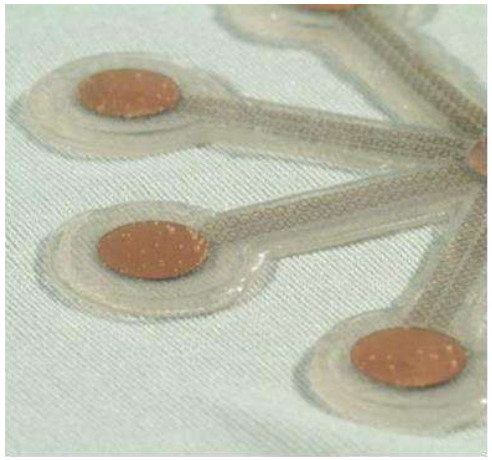
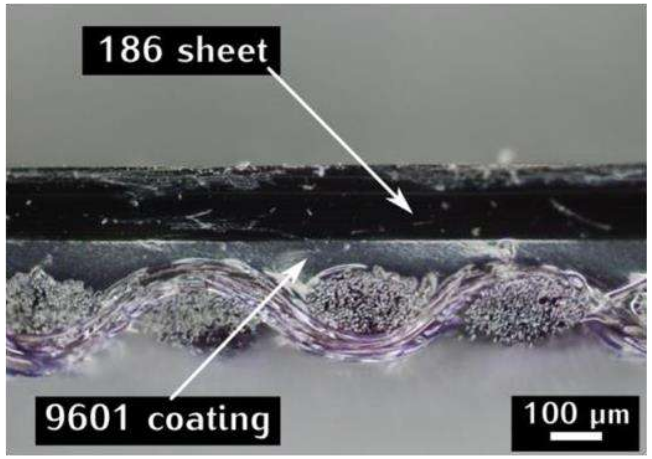
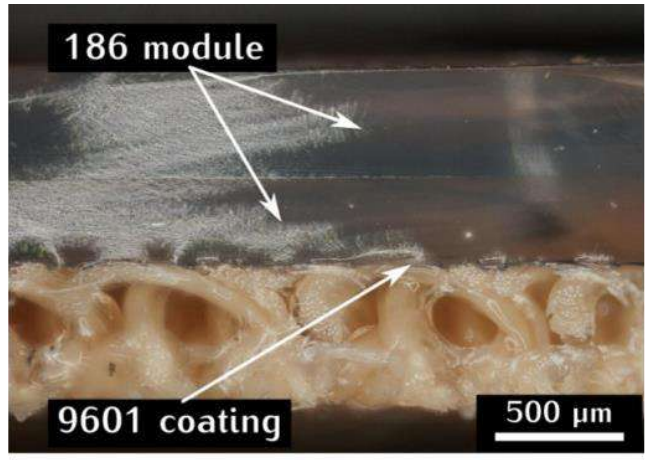
STRETCHABLE ELECTRONICS
TEXTILE INTEGRATION



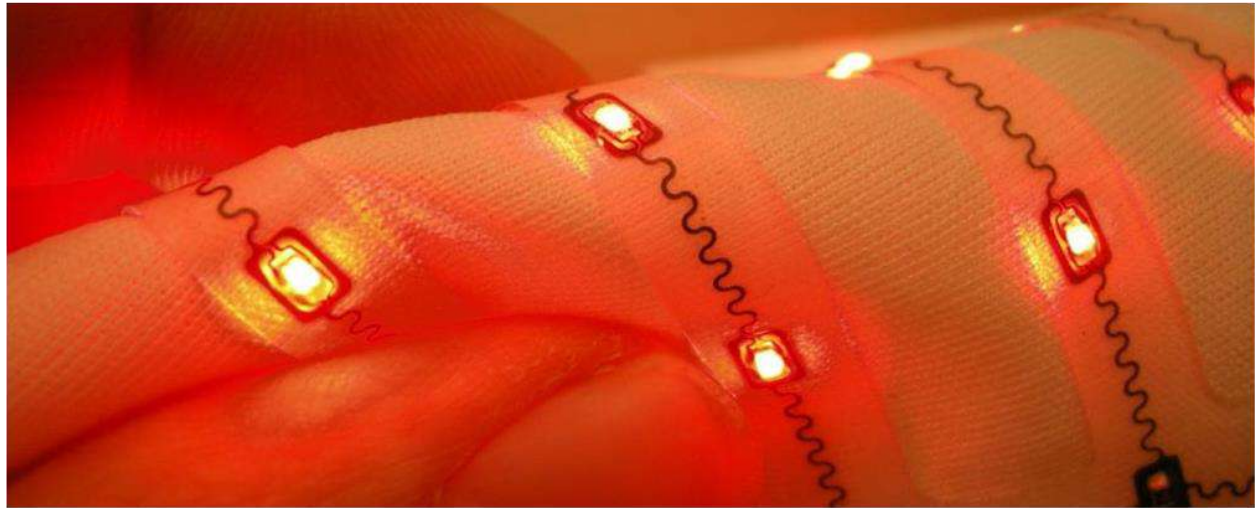
PDMS test module on a knitted fabric



Cross section: PDMS on a woven fabric



Cross section: PDMS on a knitted fabric



PU encapsulated LED array on a knitted fabric

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E-TEXTILES ARCHITECTURE @ IMEC-CMST

APPROACH

- We develop building blocks for systems as shown in the picture.
  This needs:
  - Sensing
  - Actuating
  - Powering
  - Data processing
  - Communicating
  - Interconnecting
- It's not very efficient to make very large stretchable circuits → Splitting them up in smaller parts and use **meanders** or **conductive yarns** to interconnect them

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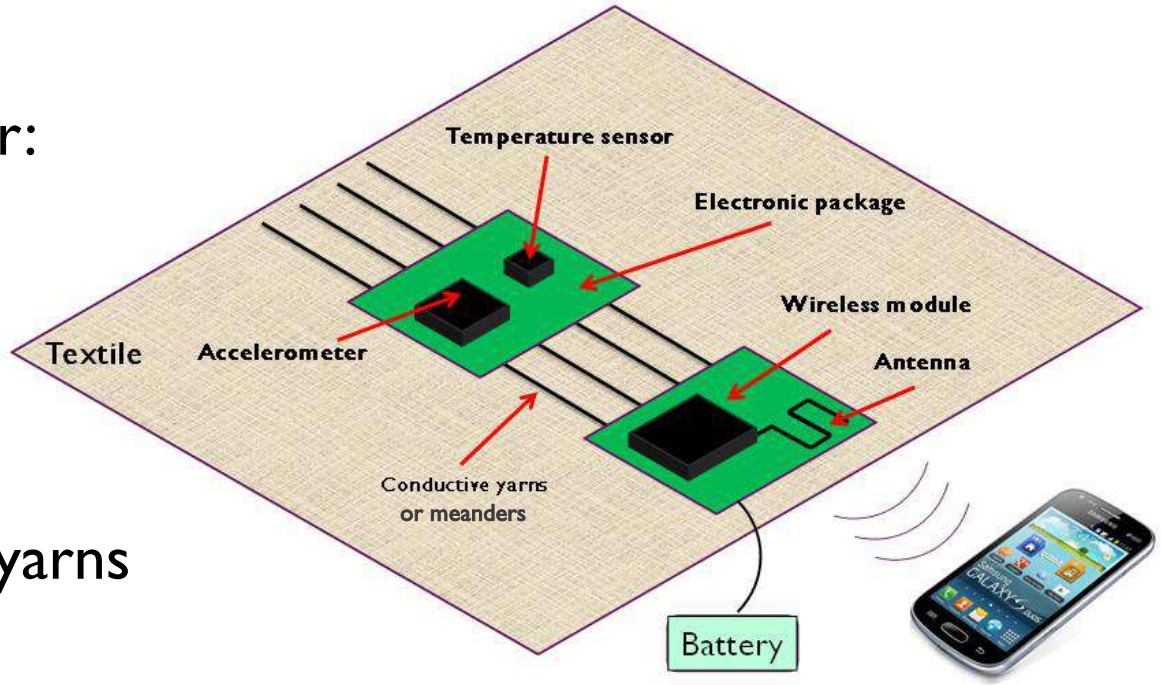
E-TEXTILES ARCHITECTURE @ IMEC-CMST

REALIZATION OF BUS SYSTEMS

- Smart nodes interconnected with each other:
  - Sensor/Actuator nodes
  - Data processing nodes
  - Wireless communication nodes
  - Powering nodes
- Stretchable interconnections or conductive yarns as way to interconnect them



Conductive yarns

Meanders

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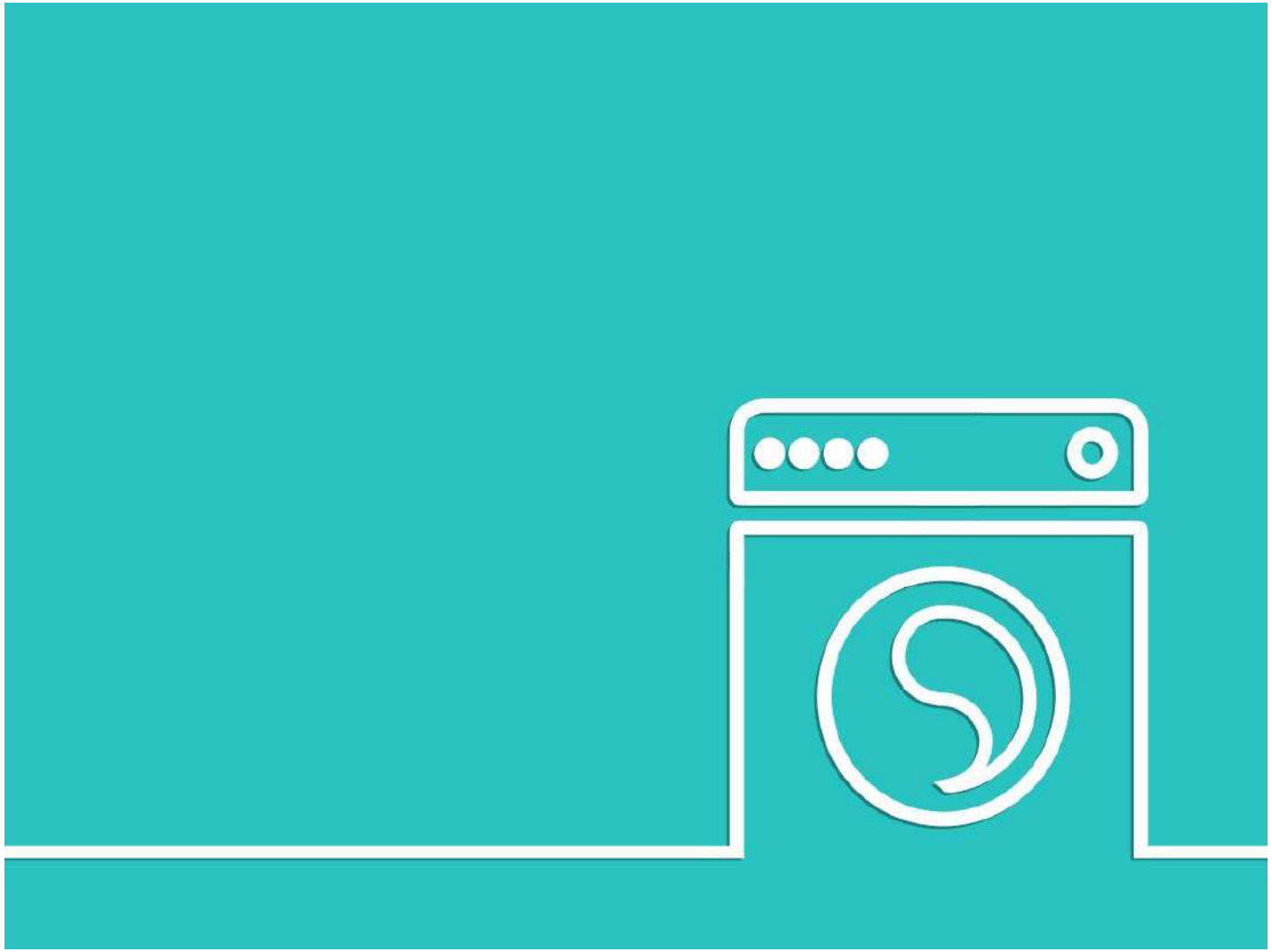
RESEARCH ON WASHABILITY

OK, BUT...

... is it washable ?



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RESEARCH ON WASHABILITY

IMPACTS

washing machine

≈

water immersion

climatic chamber

mechanical load frame

Allowing washing = allowing accelerated aging test to be part of the product normal life.

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RESEARCH ON WASHABILITY
IMPACTS

The e-textile is subjected to a bunch of loads during washing…

- Environmental
  - Temperature cycling
  - Humidity exposure
  - Immersion in liquids
  - Vibrations / accelerations
- Chemical
  - Exposure to the washing agent
- Mechanical
  - Bending, Compression, Tension, Shearing, Torsion...

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RESEARCH ON WASHABILITY
IMPACTS

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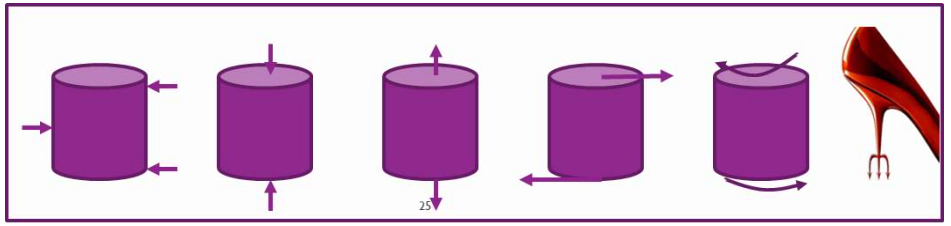

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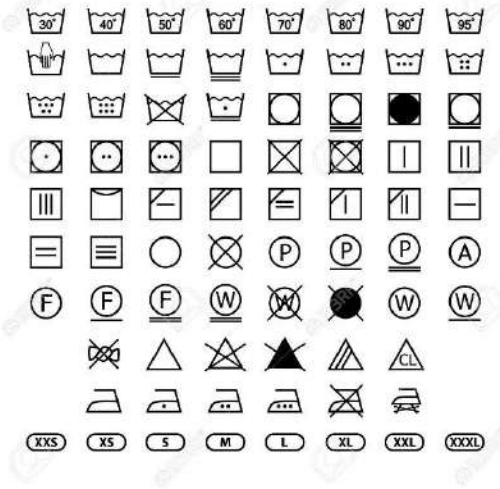
RESEARCH ON WASHABILITY
DIFFICULTIES & STRATEGIES

Difficulties in making electronics washable:

- Limitations of the **electronic components.**
- Limitations of the **interconnection technology.**
- **No standards** for textile integrated electronics washing defined yet.

Reasonable strategies for washability:

- Slow speed spinning
- Water temperature limit
- No tumble drying or centrifuging
- Protective washing bags...



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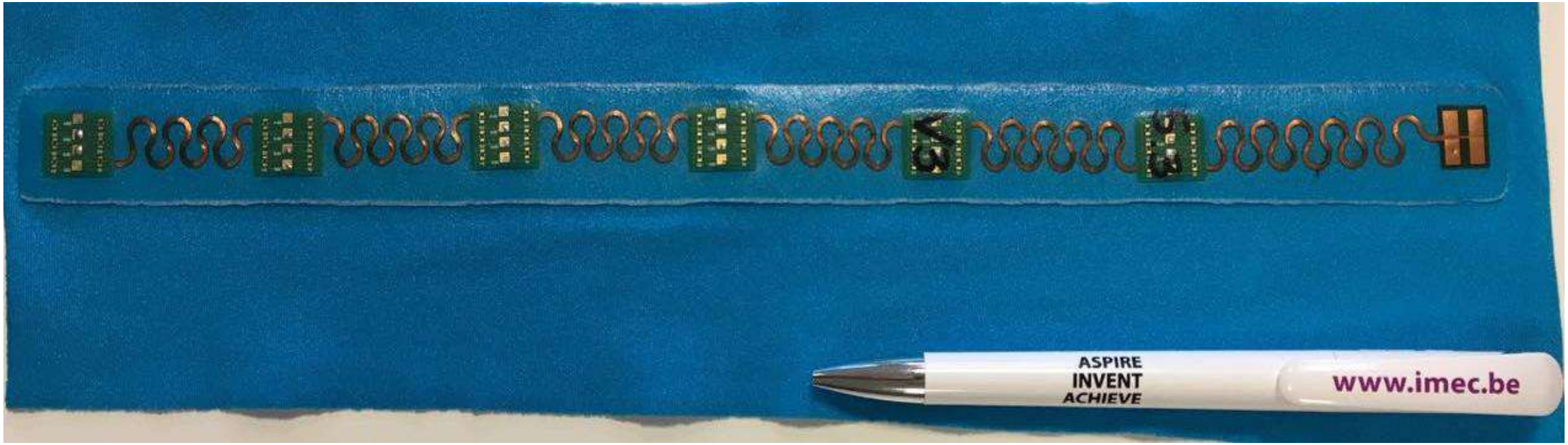
RESEARCH ON WASHABILITY
APPROACH

An example:

- Dedicated testvehicle for investigating washability
- Bus system with dummy sensor nodes



Sample encapsulated with TPU and integrated on Spandex

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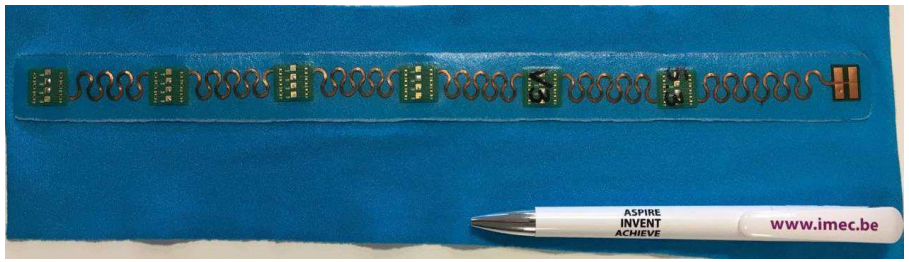
RESEARCH ON WASHABILITY
EXPERIMENTS



- Samples were made varying in:
  - Stretchable circuit design and materials
  - TPU thickness
  - Textile type jeans vs. spandex
    - Jeans: 95% denim cotton, 5% Spandex
    - Spandex: 85% Polyethylene / Polypropylene and 15% Spandex
  - PCB dummy node design

- Washing conditions:
  - ISO 6330: 2012 number 3N - Washing at 30˚C – Line drying

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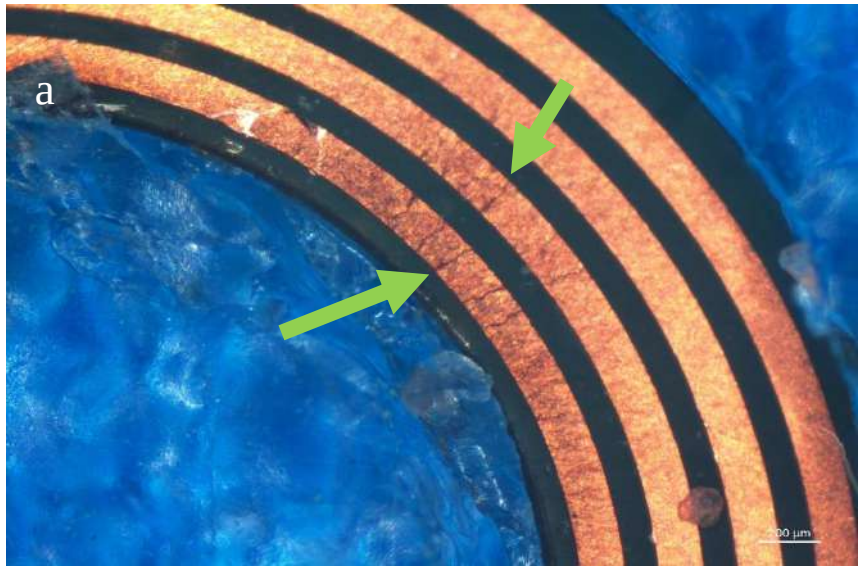
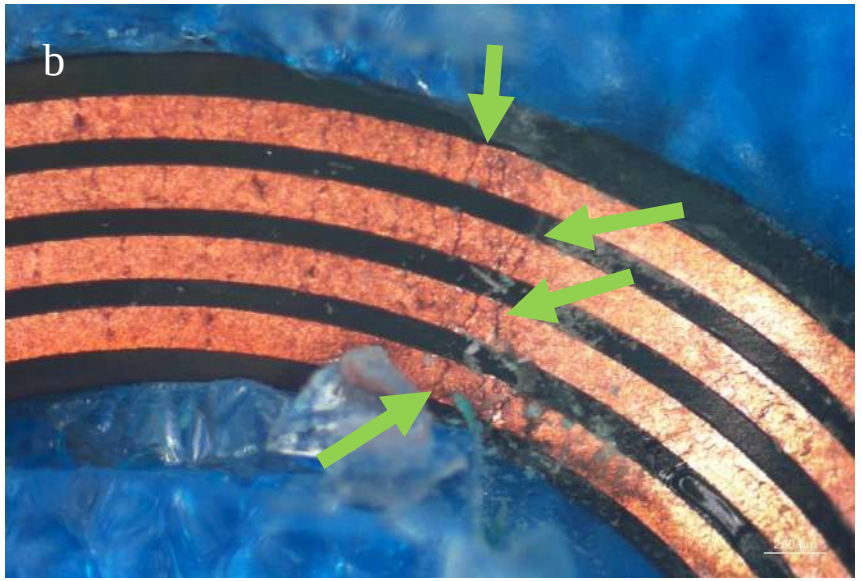
RESEARCH ON WASHABILITY
FAILURES OBSERVED DURING THE OPTIMIZATION PROCESS

- Microcracks in copper in meanders



on the top of the meander



on the contact place with PCB

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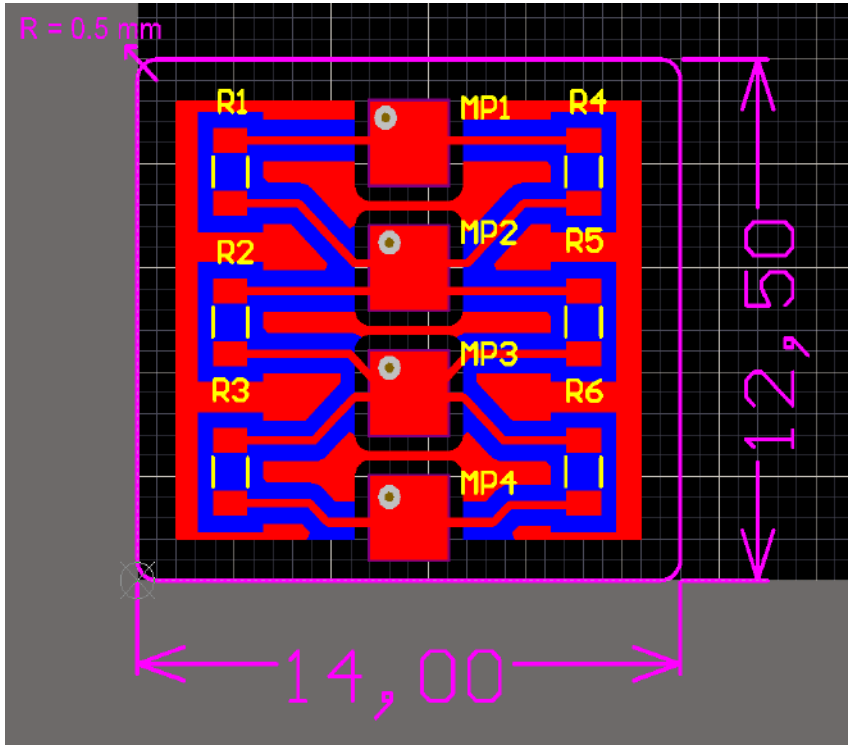
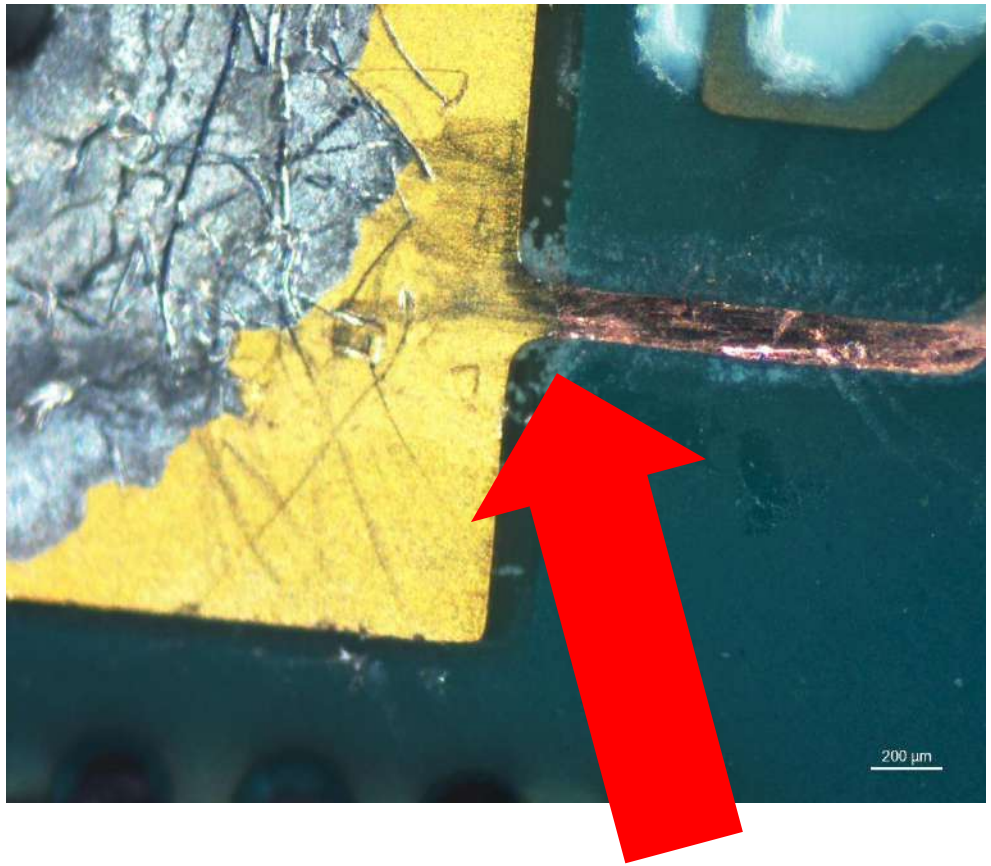
RESEARCH ON WASHABILITY
FAILURES OBSERVED DURING THE OPTIMIZATION PROCESS

- Microcracks in copper on PCB





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RESEARCH ON WASHABILITY
FINAL RESULTS AFTER OPTIMIZATION

- Samples on Jeans encapsulated with 2x2 layers of TPU were washed 100 times and presented little to no change in resistivity whatsoever, both in and out of protective bag.
- All samples on Jeans encapsulated with 1x1 layers of TPU were washed 75 times successfully. They were not tested for 100 washes; thus it is not known when they would start to break.
- From 8 samples integrated on very soft Spandex material, all samples were successfully washed for 25 cycles, and 6 survived 50 washing cycles with no significant change of resistivity. 2 samples had an increase in resistivity, both cases in a localized point and when washed out of protective bag.

Sample washed 100 times is fully functional.

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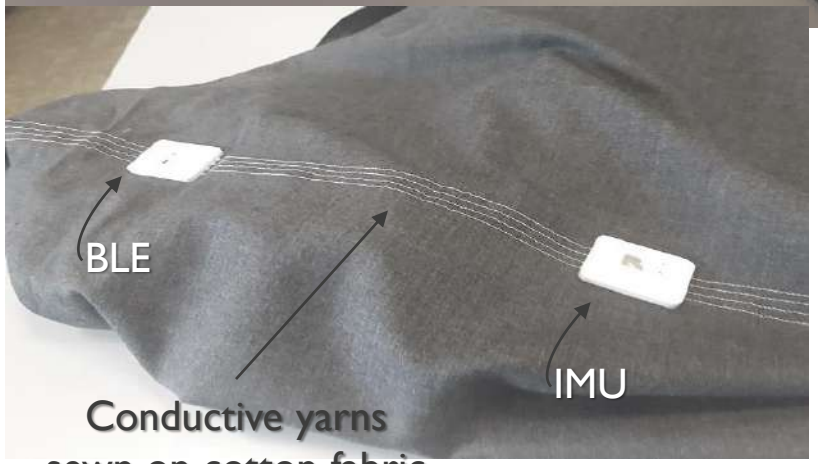
SMARTPRO PROJECT: ACTIVITY MONITORING

STRETCHABLE FABRICS WITH CONDUCTIVE YARNS AND SENSOR NODES



Sensor data is captured
on smartphone / smart home infrastructure

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Elasta

BEKAERT
better together

GYSEMANS CLOTHING GROUP

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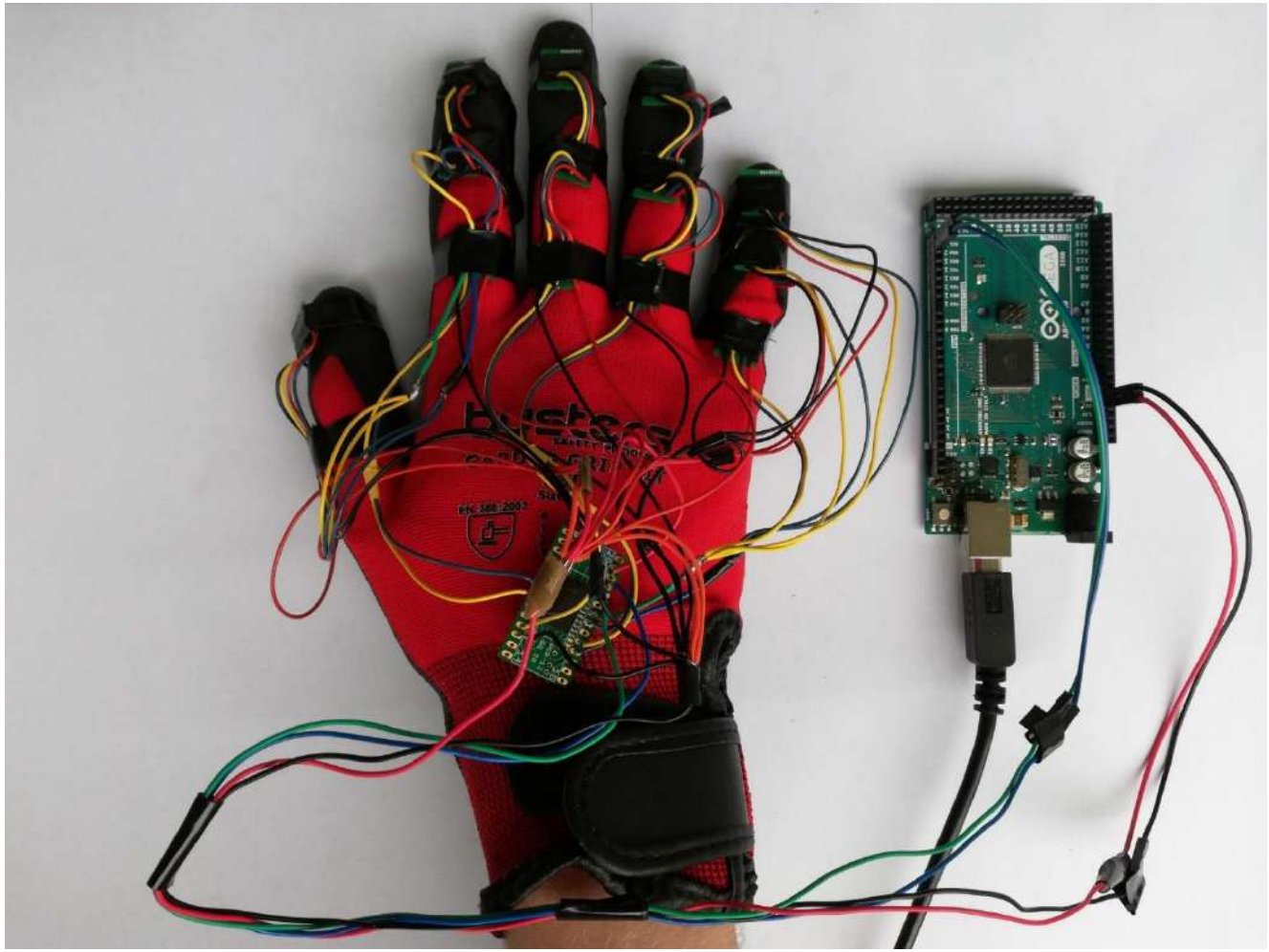
sirris

HoGent

SMART GLOVE FOR MOTION CAPTURING
PROTOTYPE

- IMU sensors are used on a bus
- Stretchable, integrated circuit is needed to reduce wiring



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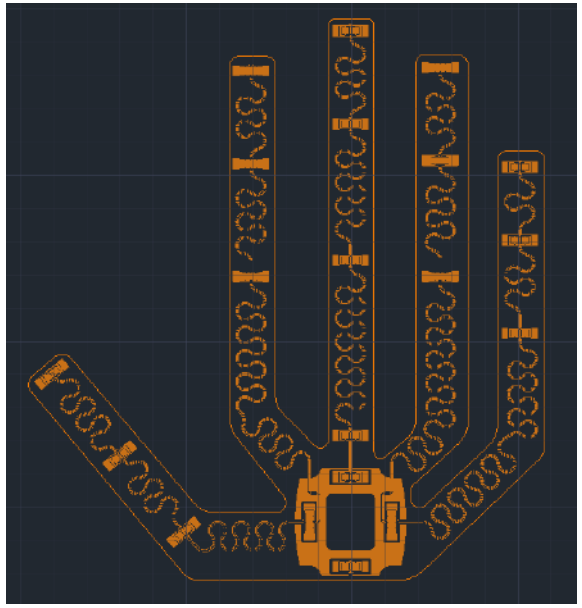
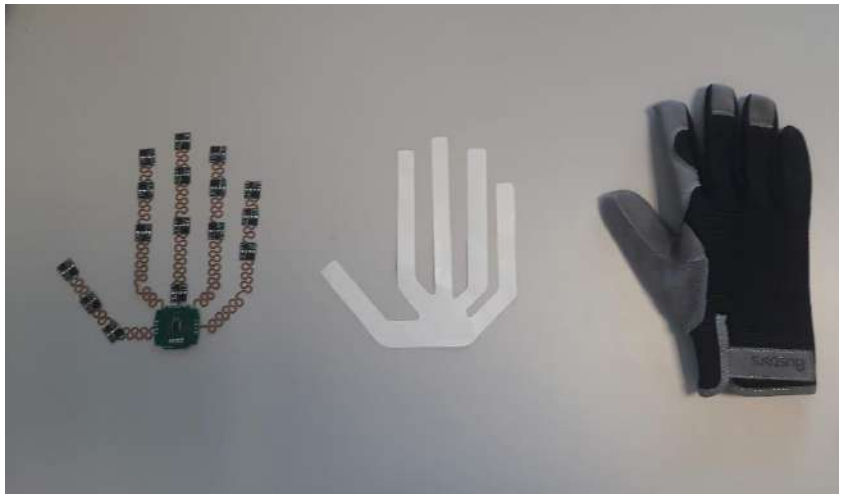
SMART GLOVE FOR MOTION CAPTURING

DESIGN PROCESS

Design of stretchable circuit



Printed circuit, polyurethane and glove



Final design

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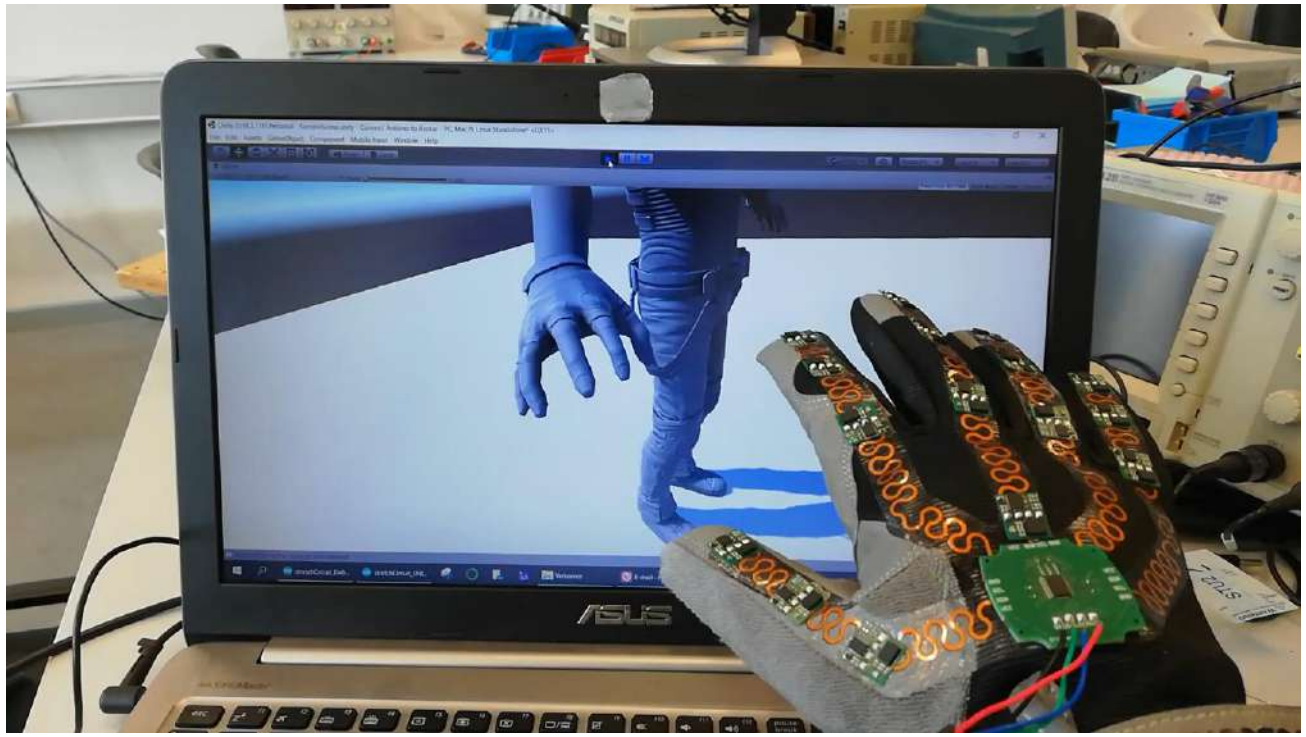
SMART GLOVE FOR MOTION CAPTURING
DEMONSTRATION

- Outputs of IMU sensors are used to control a virtual hand



- Possible applications: VR, rehabilitation, etc.

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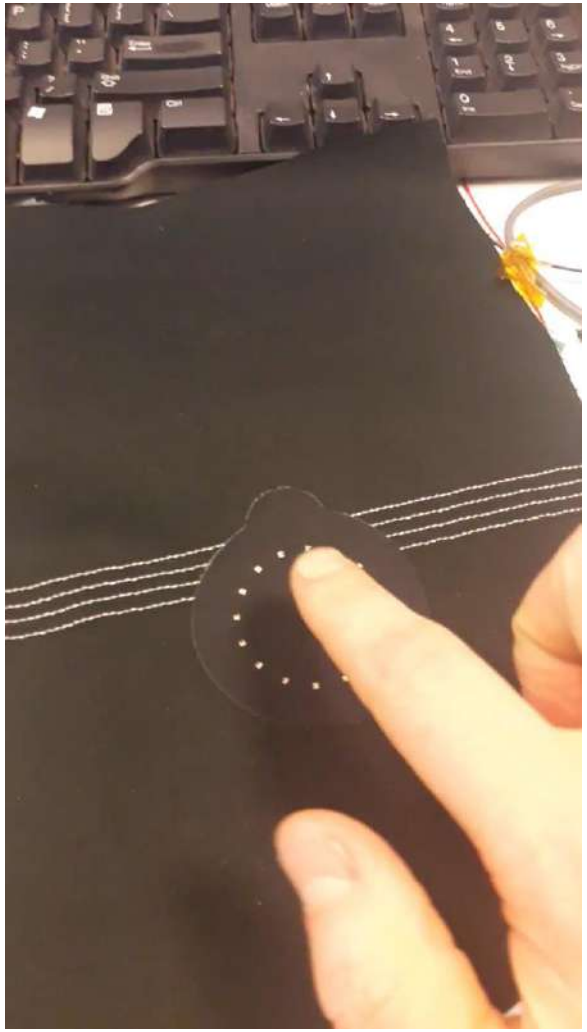
CAPACITIVE TOUCH DEMO

- Conductive yarns are used to transfer capacitive signal to external hardware and drive leds
- Flexible electronic circuit including 0,2 mm thick leds is laminated on fabric



- Possible applications: Furniture, automotive, etc.

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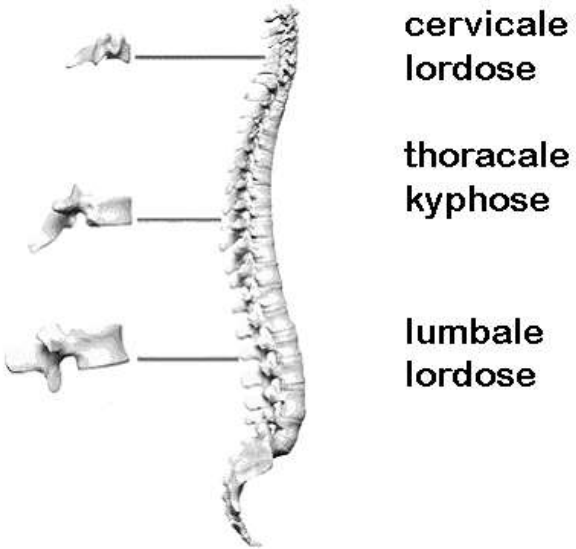
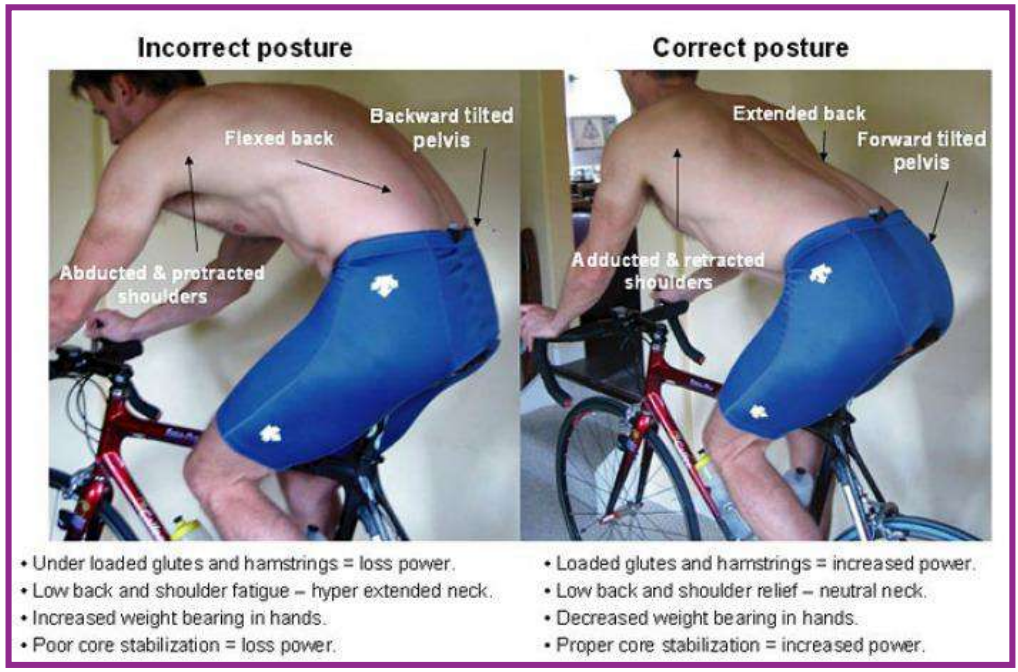
NANO4SPORTS PROJECT
BIKESHIRT WITH INTEGRATED SENSORS

- Optimal Bike Fit: midpoint between optimal biomechanical profile and optimal aerodynamic profile

OPTIMAL BIKE (FIT) ≠ OPTIMAL CYCLING POSTURE





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NANO4SPORTS PROJECT
BIKESHIRT WITH INTEGRATED SENSORS

Purpose:

- Research the effect of fatigue on the posture and movement control in pelvis and lower back ("core stability")
- Research of importance of this core stability on
  - Prestation (mechanical and metabolic load during incremental load protocol)
  - Sensitivity to injury (follow up period of 7 months of training)

REVAKI

- Development of movement sensors integrated in bike outfit to provide the cyclist with automatic feedback during training, in order to track and improve the cycling posture

IMEC-CMST

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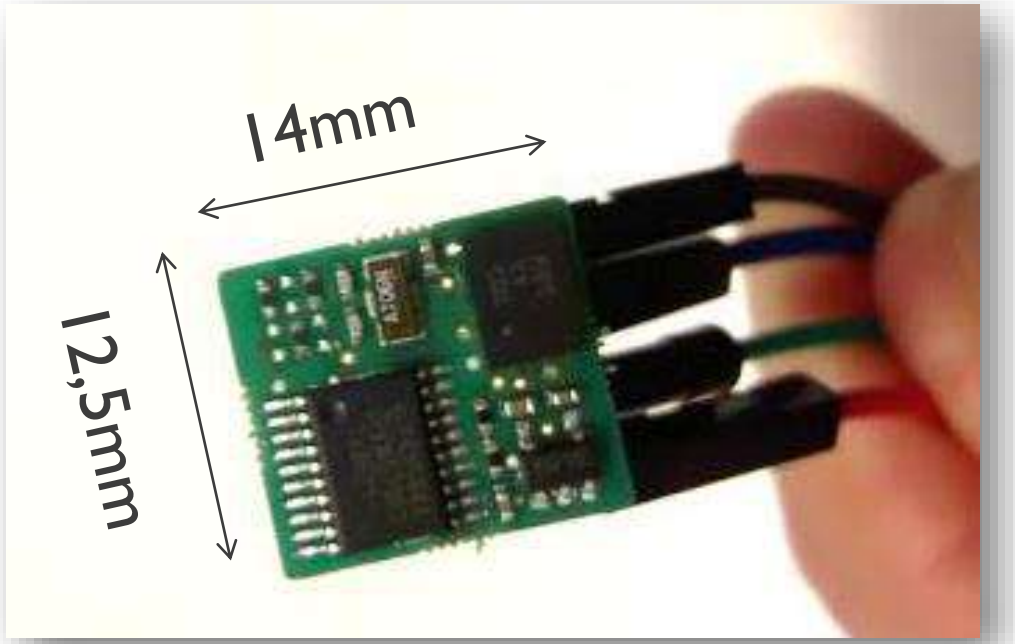
NANO4SPORTS PROJECT
BIKESHIRT WITH INTEGRATED SENSORS

- Flexible, stretchable electronics, integrated in bike outfit
- 'Smart Sensor Nodes' based on movement sensors
- Central control unit reads out all sensors on bus, and transmits through Bluetooth to smartphone, PC, custom receiver



IMU Sensor node

Central control unit

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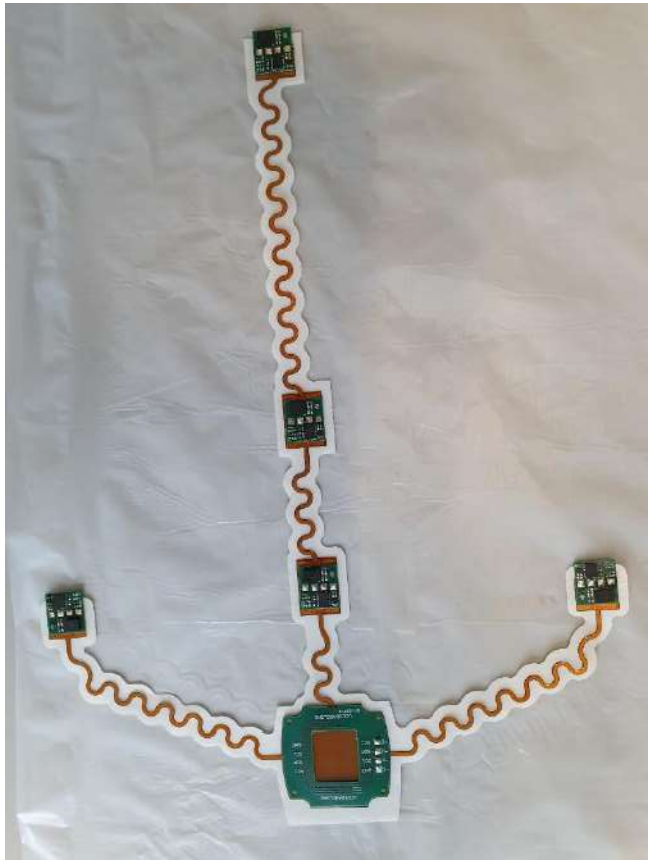
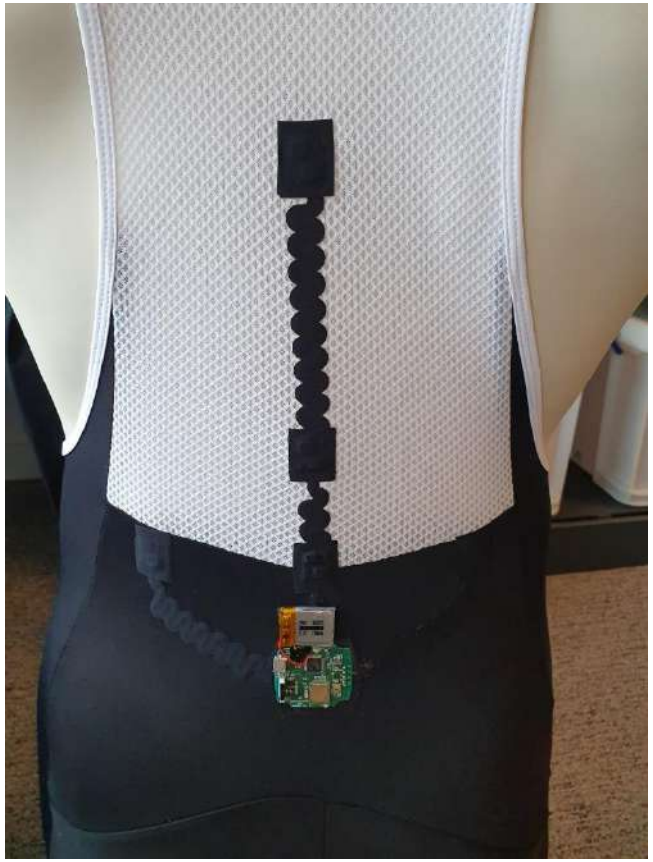
NANO4SPORTS PROJECT
BIKESHIRT WITH INTEGRATED SENSORS

- Measure curvature of lower spine
  - 3 movement sensors along spine
- Measure hip movement
  - 2 movement sensors at hip
- 50Hz readout
- Bluetooth





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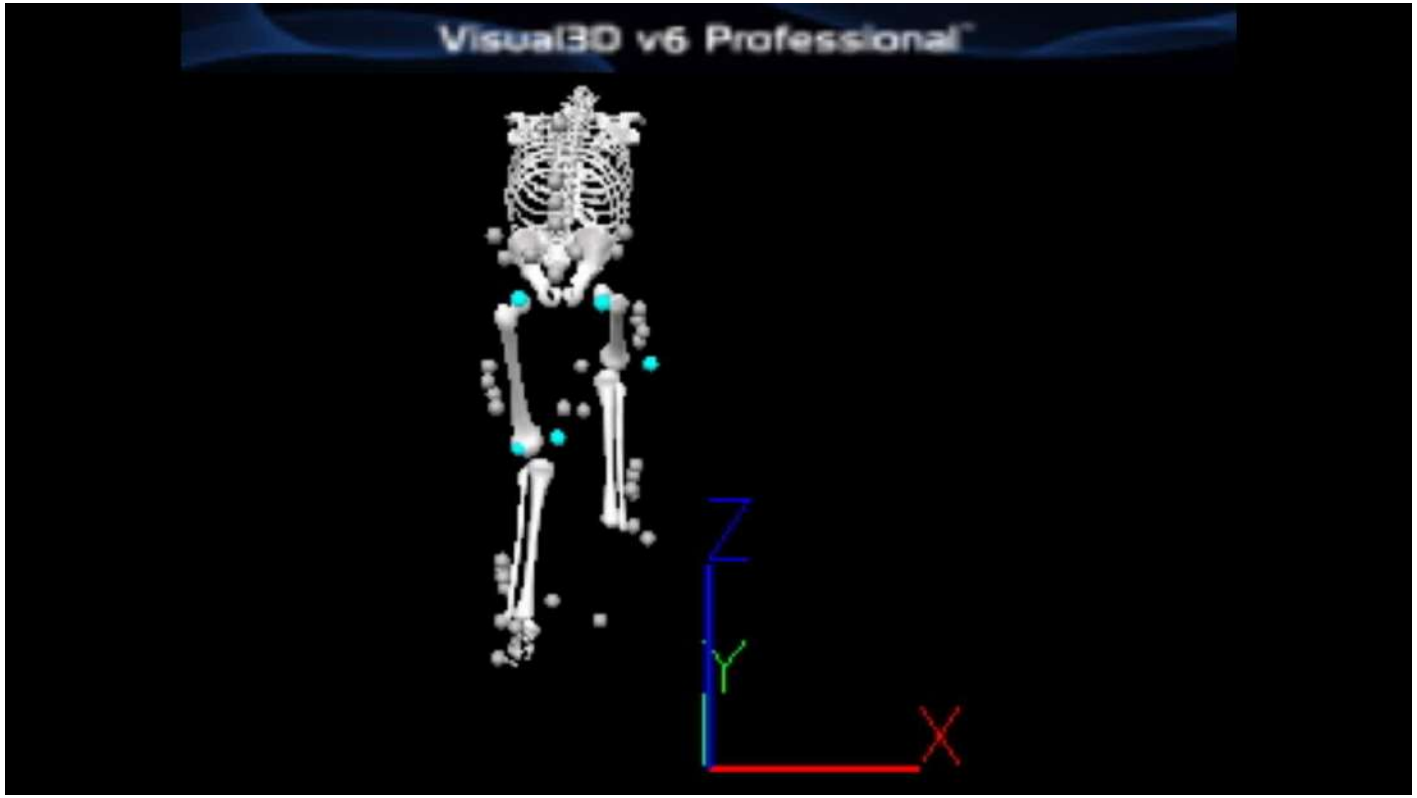
NANO4SPORTS PROJECT

BIKESHIRT WITH INTEGRATED SENSORS



Functional prototypes are available for measurements.
Now we are focusing on improving the reliability.

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LEDS IN HOME TEXTILE

- Woven fabric, 15 m x 2 m
- > 2500 Leds integrated
- Interactive with touch

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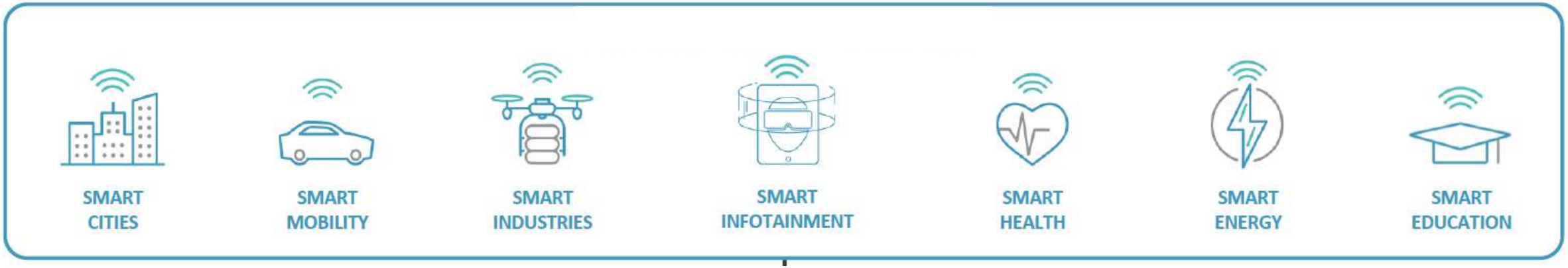
CONCLUSIONS

- The big picture for e-textiles is extremely promising.
- There is an unquestionable potential when combining the comfort, feel and look of textiles with the functionality, connectivity and intelligence of electronics.
- E-textiles can be of benefit for a lot of application domains:



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CONCLUSIONS

- At CMST, we focus on development of packaging technologies, investigate reliability of these E-Textiles
- In the scope of different projects, we realize prototypes

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