



Centre for Nanotechnology  
and Smart Materials



# Conductive Fibres for Sensing and Energetic Applications



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CEO

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Theme:

**World Textile –  
Growth & Great Opportunities**

# Summary

About CeNTI and global CITEVE group

Facilities and Equipment

Fibres for Sensing Applications

Fibres for Energetic Applications

Printed sensors on textiles

New developments





# About CITEVE Group



# CeNTI belongs to CITEVE Group











# CITEVE / CeNTI technology campus





# Your contacts in Bombay



Mr Jacob Kutty

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Mrs Arpana Shah

([arpana.shah@india.citeve.com](mailto:arpana.shah@india.citeve.com))



# Testing Services



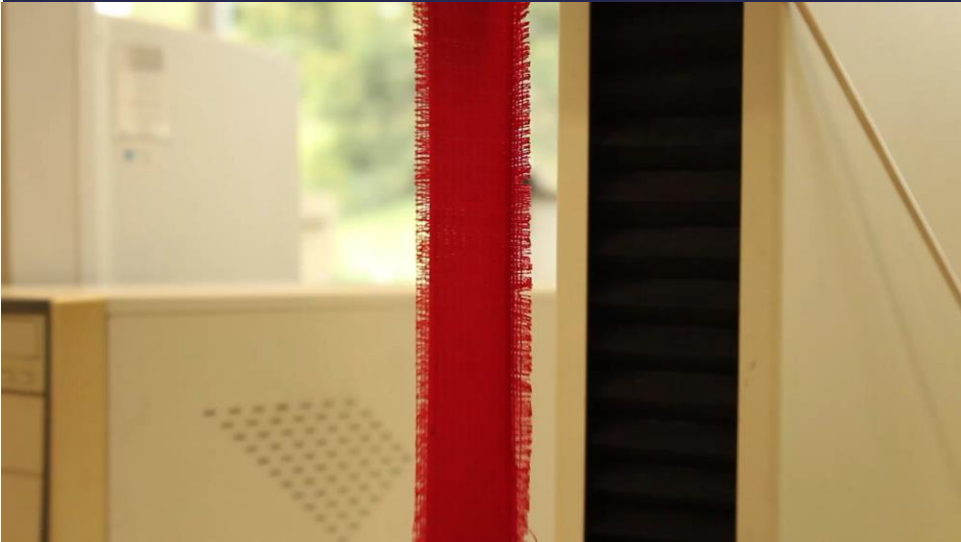
- Quality control
- Product Performance Assessment
- Defect identification and analysis
- Lab management consultancy



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# Lab facilities



- Physics and Comfort
- Chemical & Toxicology
- Microbiology/Cyto-toxicology
- Electronic Microscopy (SEM)
  - Fibre identification
  - Defects analysis
- Metrology
- Product performance evaluation
  - Fire / Heat
  - Volatile Organic Compounds (VOC)
  - Rain / water protection
  - Thermal / Comfort
  - Behaviour facing electricity
  - Industrial Laundry
  - Light and UV





- Accredited laboratories ISO/IEC 17025 by Instituto Português de Acreditação
- European co-operation for Accreditation
- “Third part laboratory” by US Consumer Product Safety Commission (CPSC)
- International Laboratory Accreditation Cooperation
- Notified Body for CE Mark

# Product & Process certification







# Technology & Engineering Services



- R&D
- Consulting
- Product Development
- Prototyping
- Scale up
- Digital business



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Sustainable Production  
Design & Fashion Intelligence  
Training & Coaching  
Innovation & Entrepreneurship  
Standardisation  
Clusterisation and  
intercluster cross-fertilisation  
Industry 4.0 & Shop of the Future



Other areas of activity





## About CeNTI



# High Level Shareholders



Universidade do Minho



# Focus

3 Main Competence Pillars

3 Main Targets

3 steps Philosophy

Many Base Materials / Substrates

1 focused mission:

# Nano for Industry







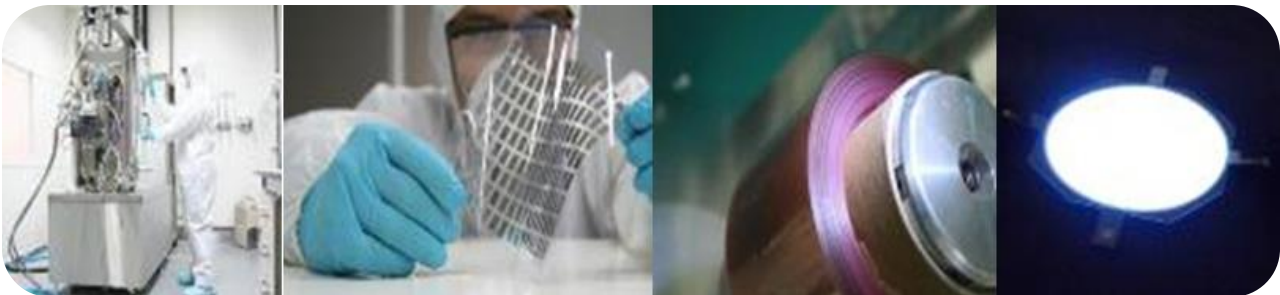
# Three Main Competence Pillars

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# Three Main Competence Pillars



① Functional Materials & Solutions



② Smart Materials & Systems



③ Modelling Design & Engineering





## Three Main Targets

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# Three main targets

## Automotive & Aeronautics



## Architecture & Construction



## Sports, Health, Protection & Well-being





## 'Three steps' philosophy

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Many Base Materials / Substrates

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## Figures and Facts

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# Brainware

50

50 FTE (Full-time  
equivalent) high skilled  
professionals

~ 10 – 15

Students



# Patents

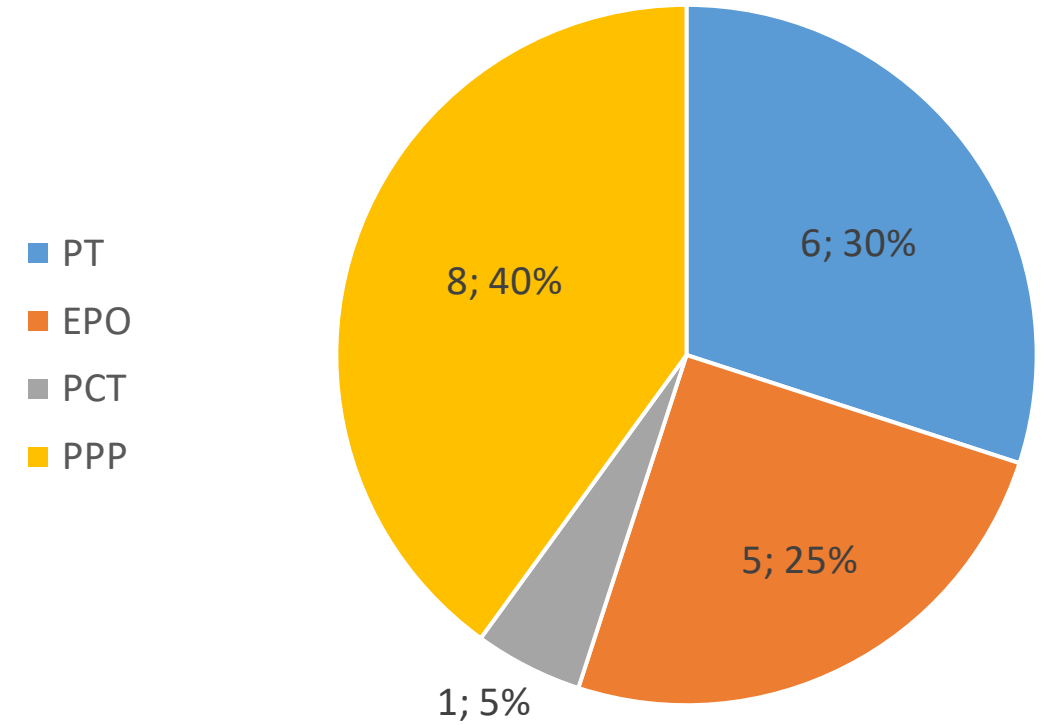
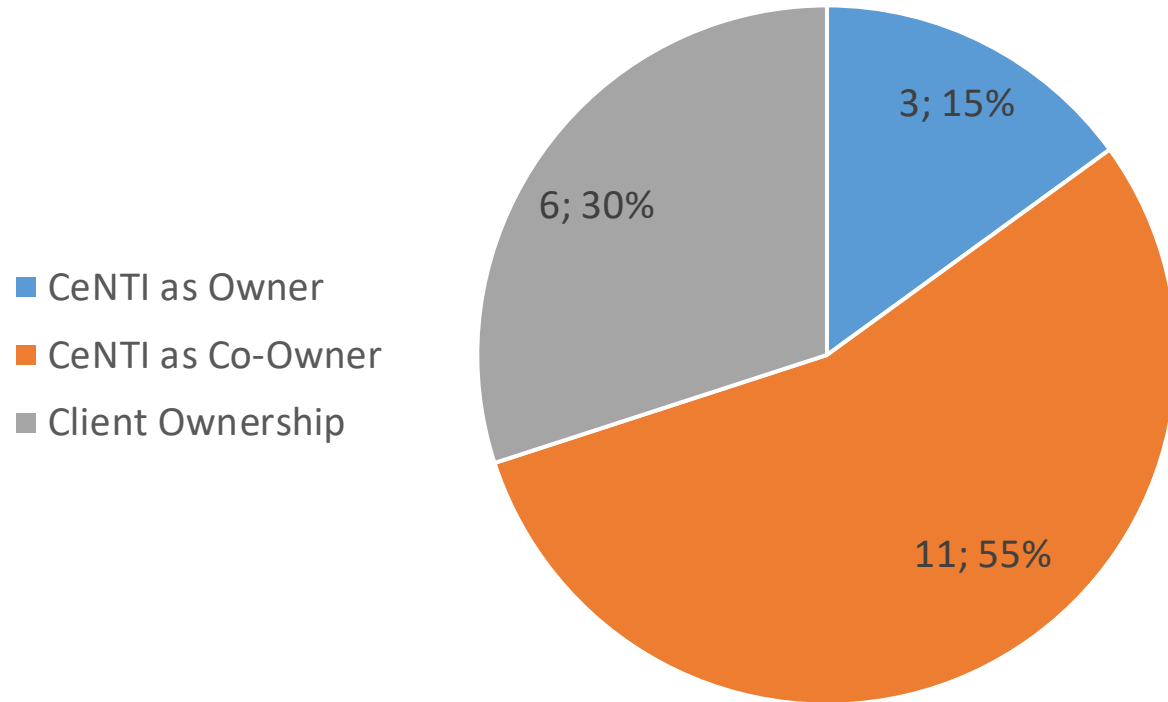
36 in total

20 during 2015





# 20 Patents during 2015





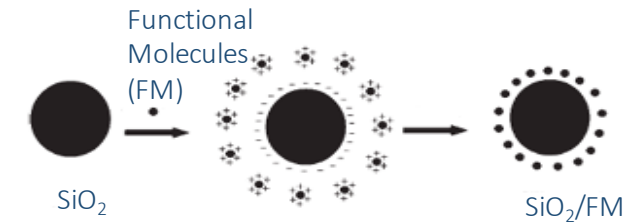
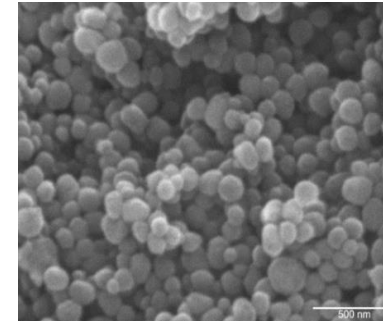
# Competences

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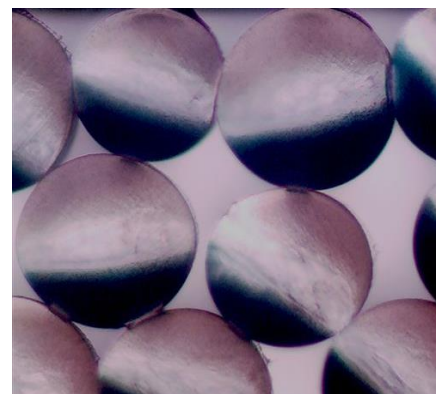
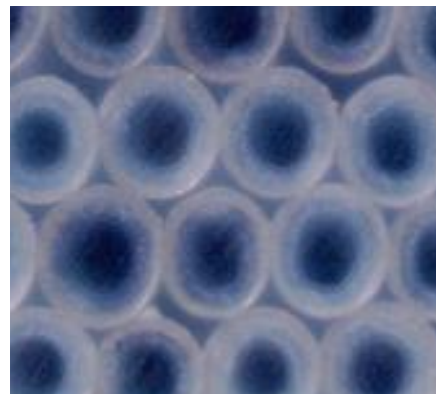
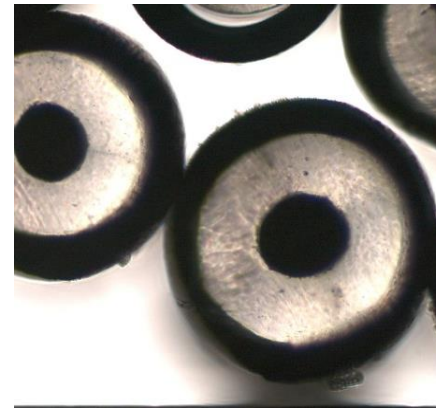
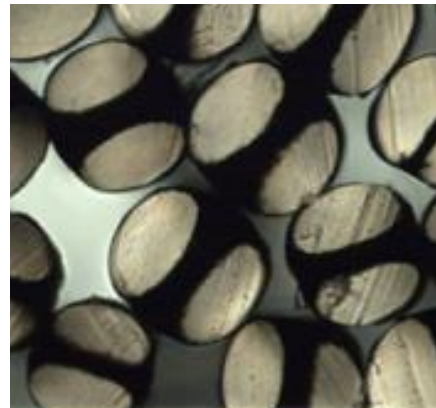
- **New nanomaterials: SiO<sub>2</sub> - based nanocomposite synthesis**

- Synthesis of silica based nanomaterials
- Development of customized nanomaterials from lab scale (2L) up to pilot scale (650 L)
- Examples - nanomaterials for:
  - Antimicrobial
  - Anti-scratch
  - Super oleophobic and Super hydrophobic
  - Self cleaning
  - Anti counterfeit.....





Development / Production of bi-tri  
component fibers doped with  
nanomaterials

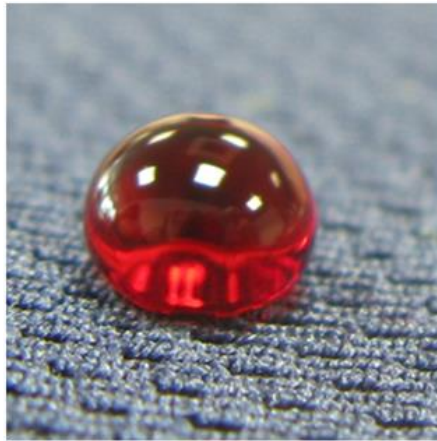






# Surface Functionalisation

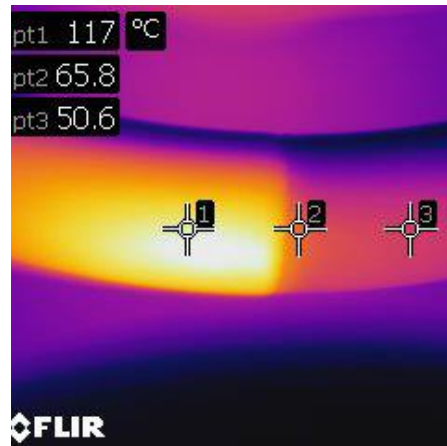
Easy/Self Cleaning



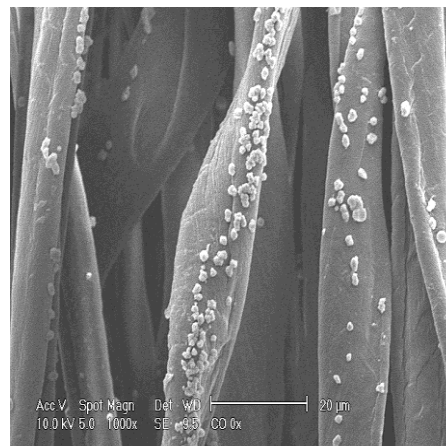
Bio Colouring



Thermal Management



Anti Microbial



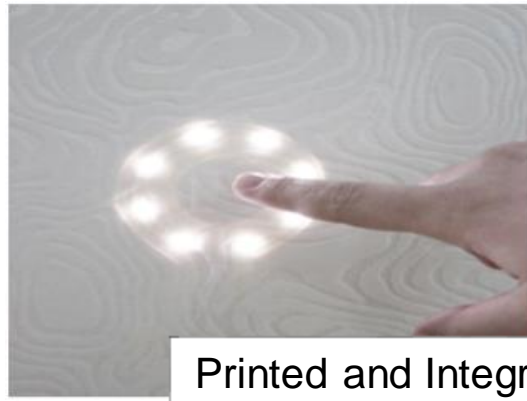
- R2R UV Surface Modification
- Ozone Surface treatment
- Wet Coating Nanoparticle Dispersion
- Plasma Surface Modification;
- Polymeric Composite Coatings;



# Printed Electronics



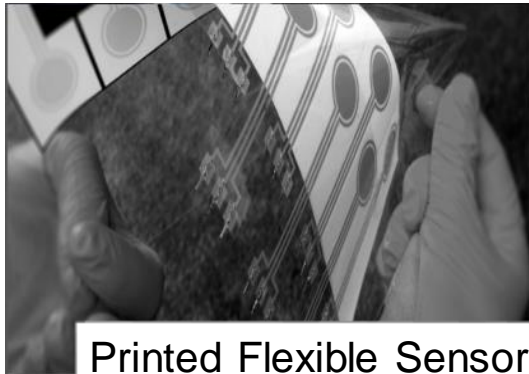
Direct Printing of  
Intelligence



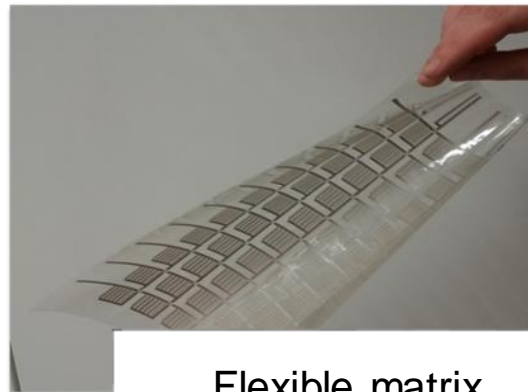
Printed and Integrated  
Lighting Device



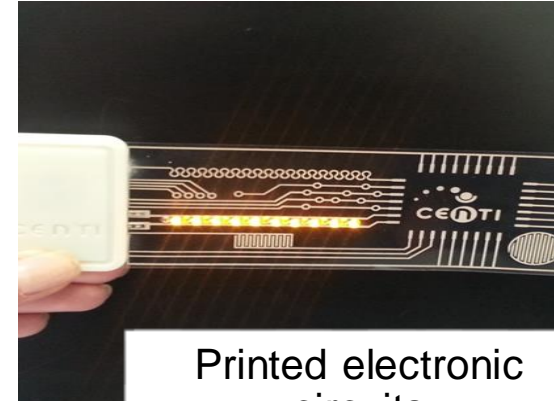
Stretchable



Printed Flexible Sensor  
Actuator



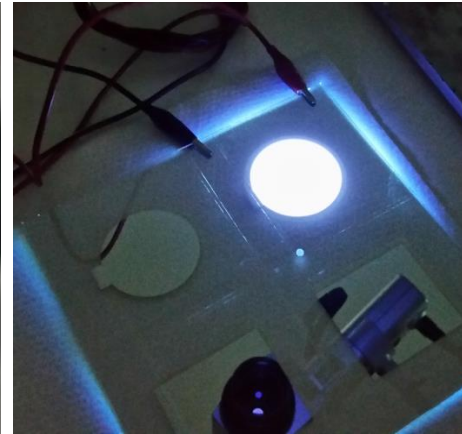
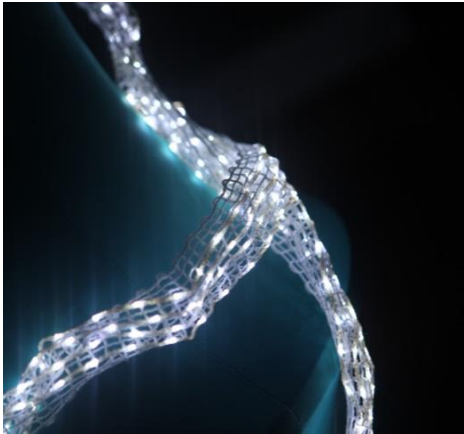
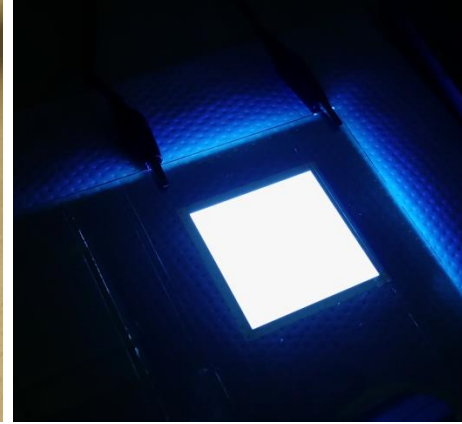
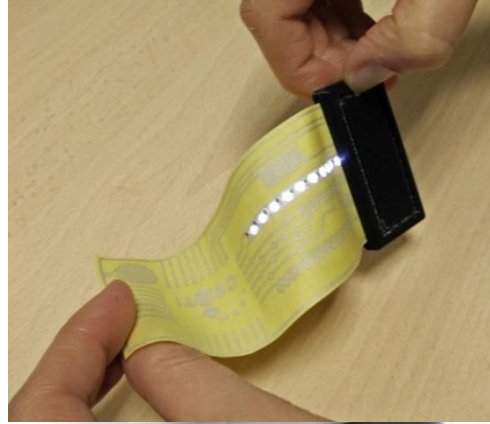
Flexible matrix



Printed electronic  
circuits



# Printed Lighting

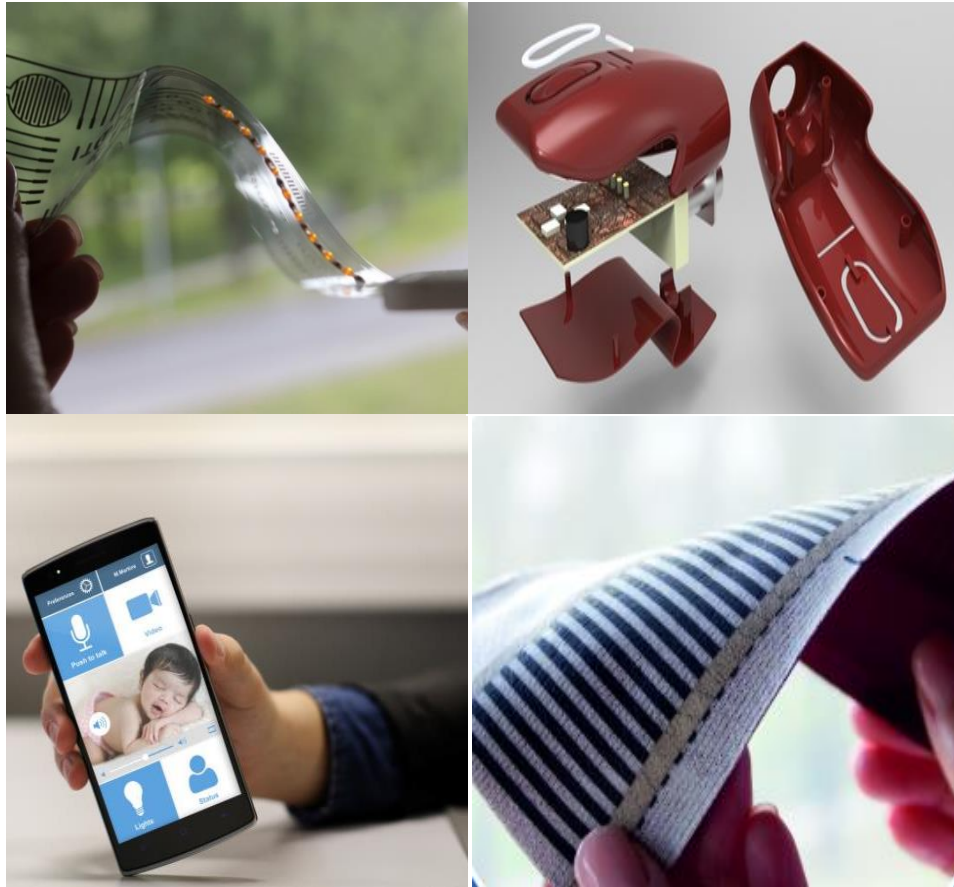






# Hybrid Smart Systems

substrates;



- ① Development of printed-bulk electronics hybrid systems integrated onto and into flexible and rigid structures;
- ① Combination with Integrated/Printed lighting Elements;
- ① Hardware and software development – Mobile App;
- ① Printing and coating process

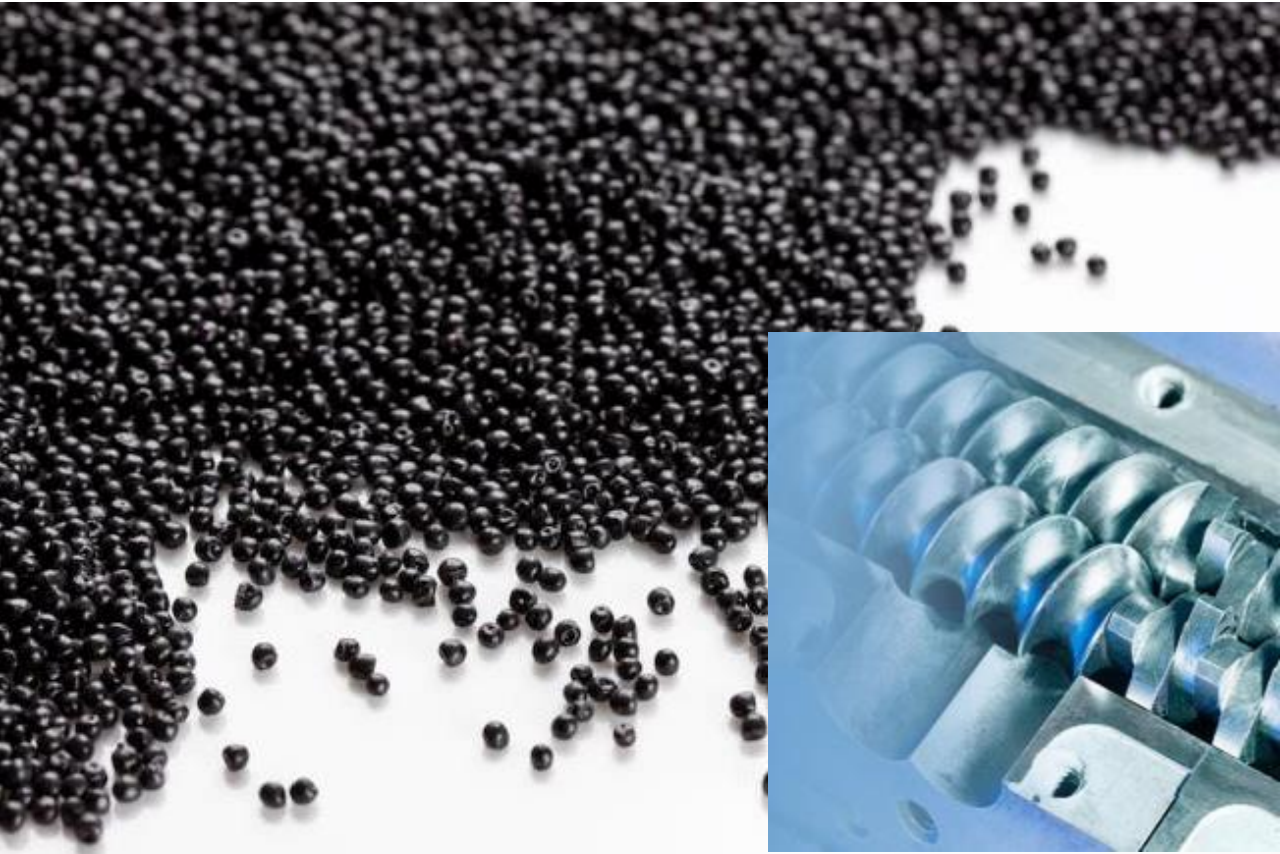


# Facilities & Equipment's

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# Polymer compounding



- ① Development of customized compounds for specific applications
- ① Throughput : up to 24 kg/h
- ① Temperature: up to 450°C
- ① Ability to add liquids, powders and pellets
- ① Different screw profiles available  
For PP, PE, PA66, PLA, PET, PEEK



# Non conventional Fibres

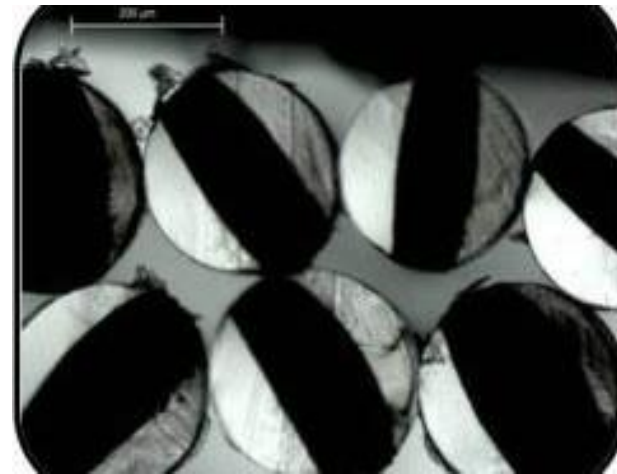
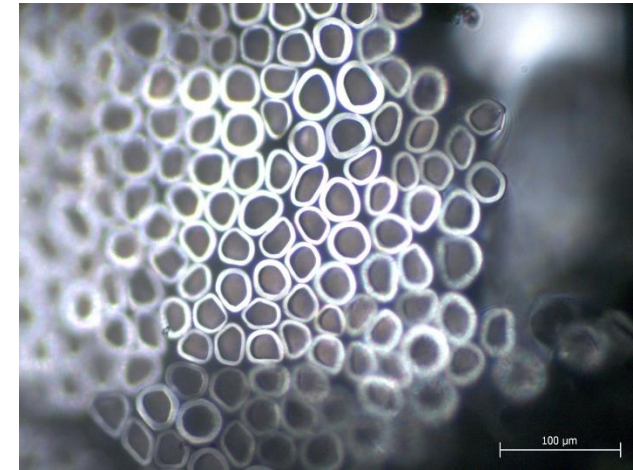
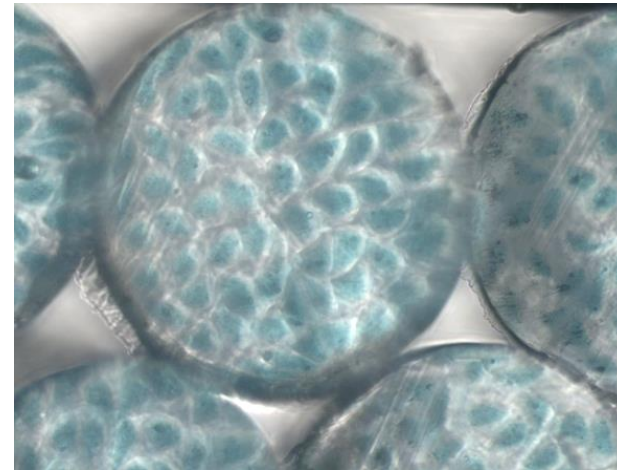
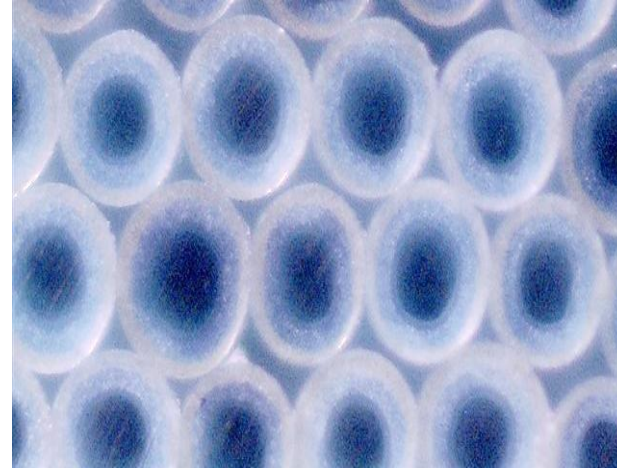
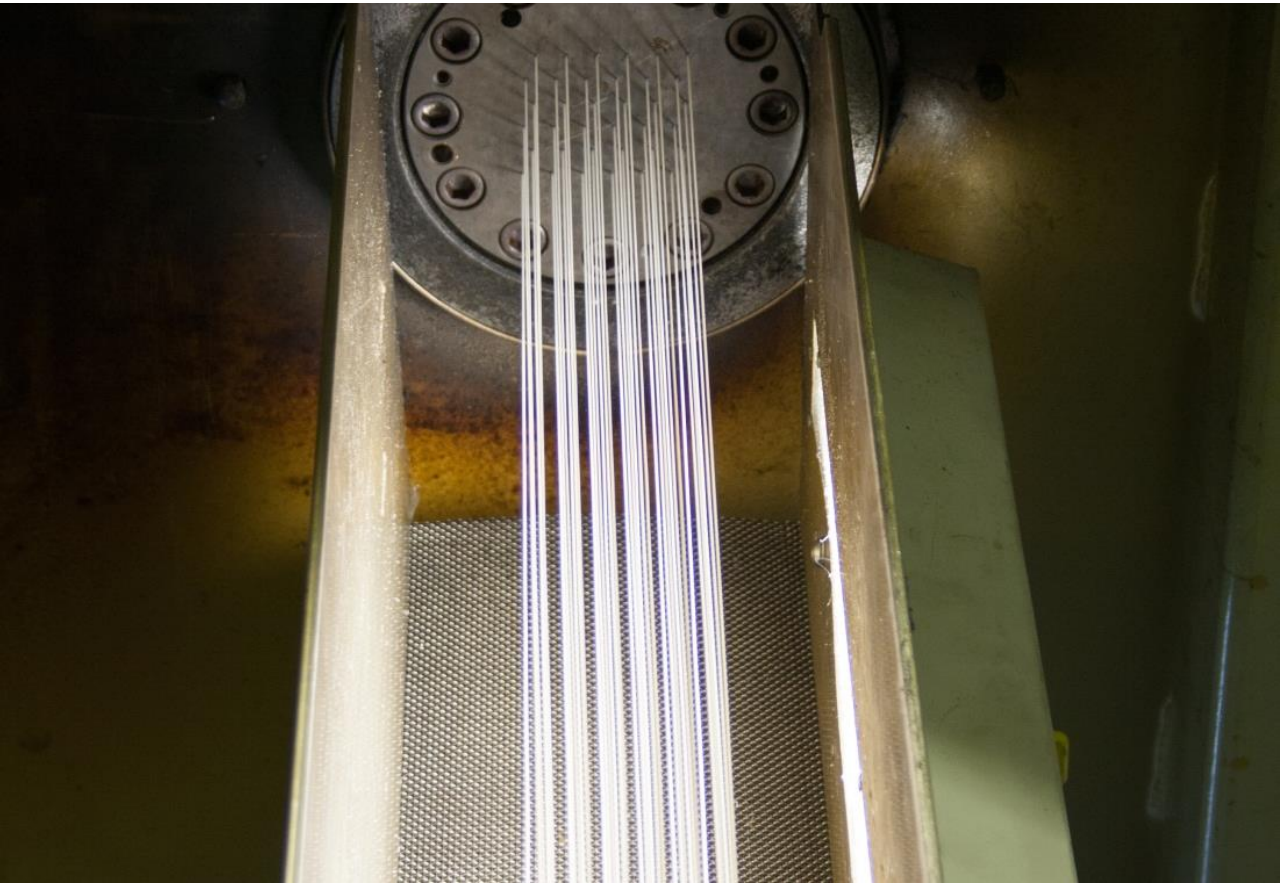


- ① Tri-component fibre technology (pilot scale)
- ① High temperature capability (up to 450°C )
- ① Processing of aggressive corrosive polymers (ex: PVDF)
- ① Laboratory and pilot scale production
- ① Electrospinning (lab scale)
- ① Wet spinning (lab scale)





# Non conventional Fibres

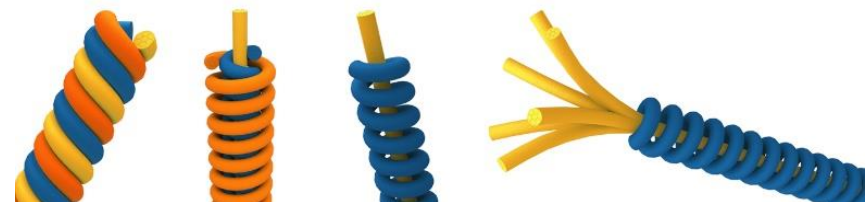


# Non conventional Fibres

## Twisting Technology



- ① Several different twisting and cabling possibilities;
- ① Cabling and covering easily achieved and alternated, with minor process changes;
- ① No yarn preparation nor rewinding after twisting required;
- ① Possibility of blending technical yarns with stronger and/or with more suitable physical properties.





# Opportunity

From

“Sensors in textiles”

To

“Textiles as sensors”







# Fibres for Sensing Applications

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# Examples

## Orthopedic Diagnosis Systems

### Piezoelectric Sensor:

- Monitors vibration and frequency;

### Hardware IO Box:

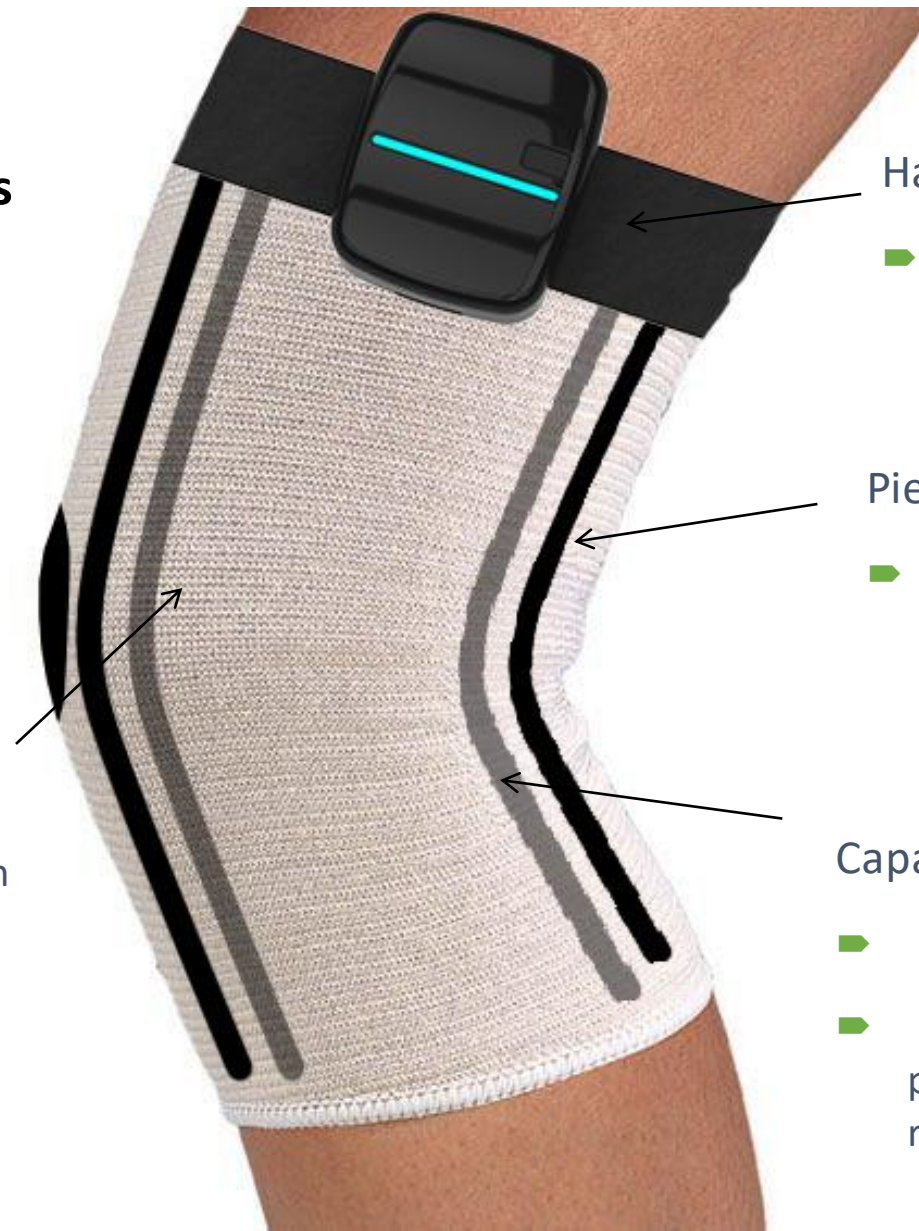
- Integrates all data acquisition and transmission hardware;

### Piezoresistive sensor:

- Monitors bending and applied pressure/tension and also translation movement;

### Capacitive Sensor:

- ON/OFF system:
- Monitor variation of perimeter of knee and rotation movement.



# Two main approaches

Fibre sensors

Printed electronics





# Fibre sensors

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Mechanical sensing

# Fibre Sensors



- ① Fibre based strain sensors for several applications (detection of mechanical failure or health monitoring)
- ① Functional wearable fibres for clothing and non clothing applications
- ① Use of scalable tri-component melt-spinning process

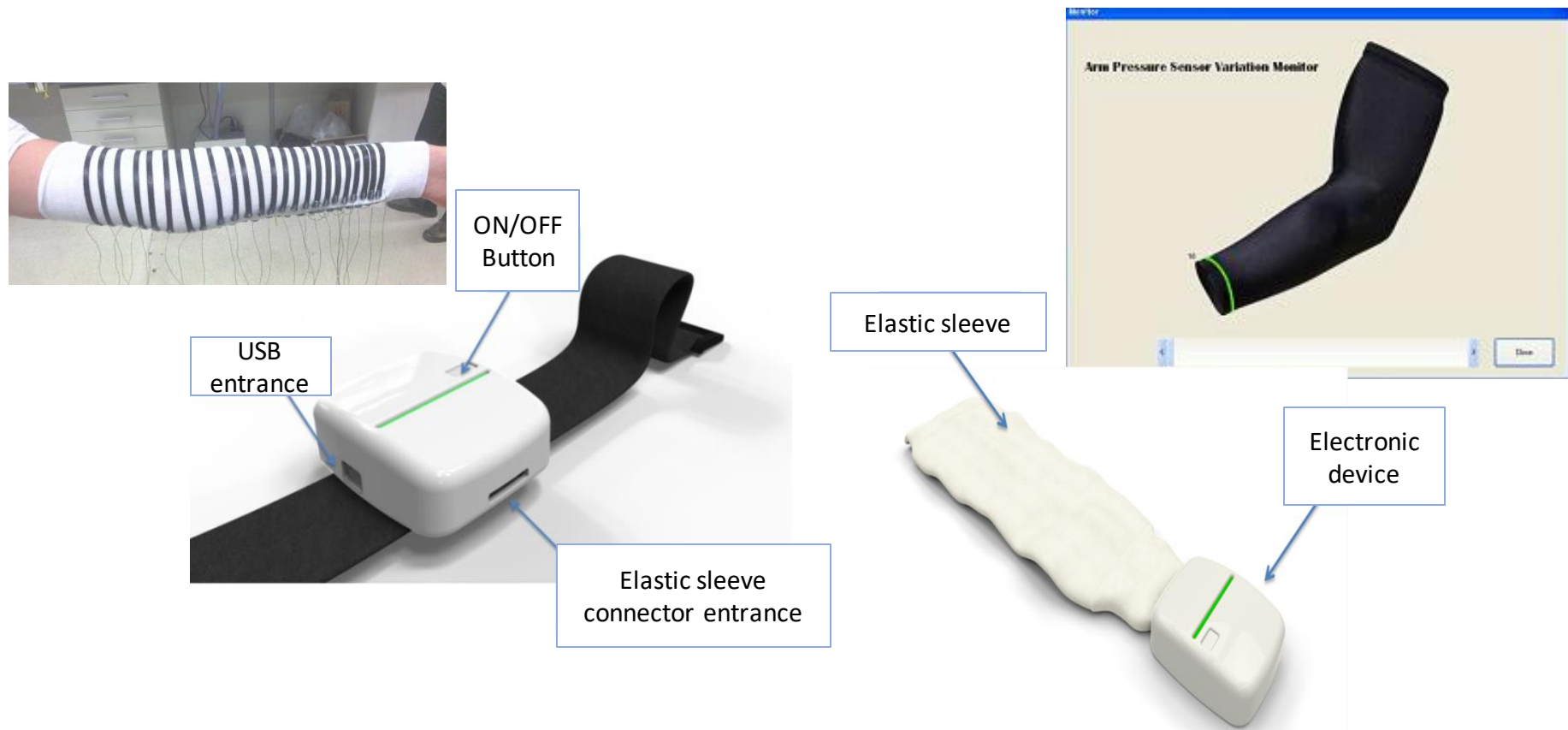






# Piezoresistive Sensors

- ① **Changes the electrical resistance when a mechanical strain is applied.**
- ① Sleeve with integrated sensors that enables the monitoring of the arm perimeter in order to assess the evolution of lymphedema;



# Strategy

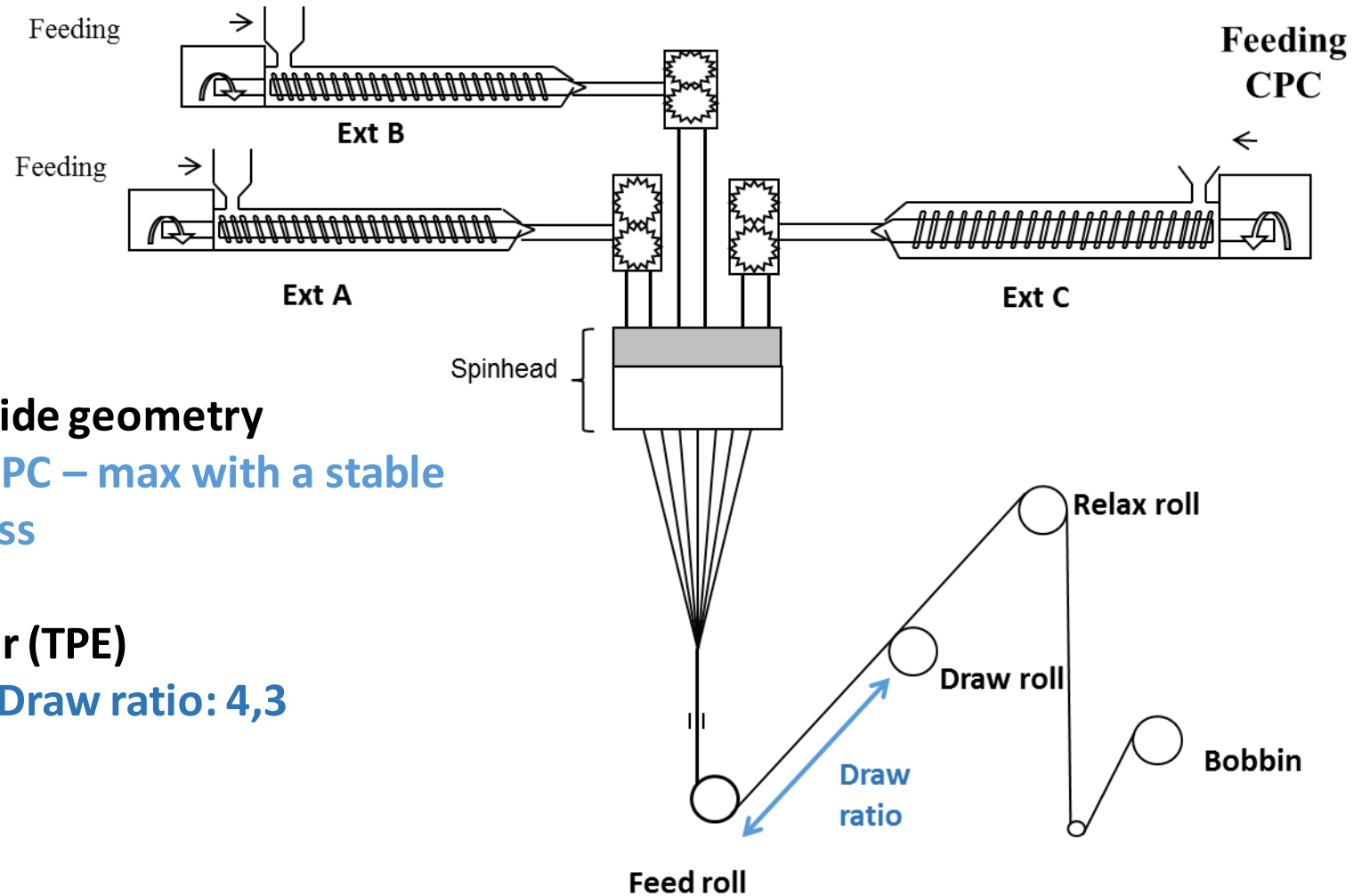


- ① Piezoresistive strain sensor fibres
- ① Cross section configuration
  - ① Side-by-Side
- ① The materials
  - ① Thermoplastic Elastomer (TPE)
  - ① Carbon-based conductive compound (CPC)





# Spinning trials



**Side-by-side geometry**

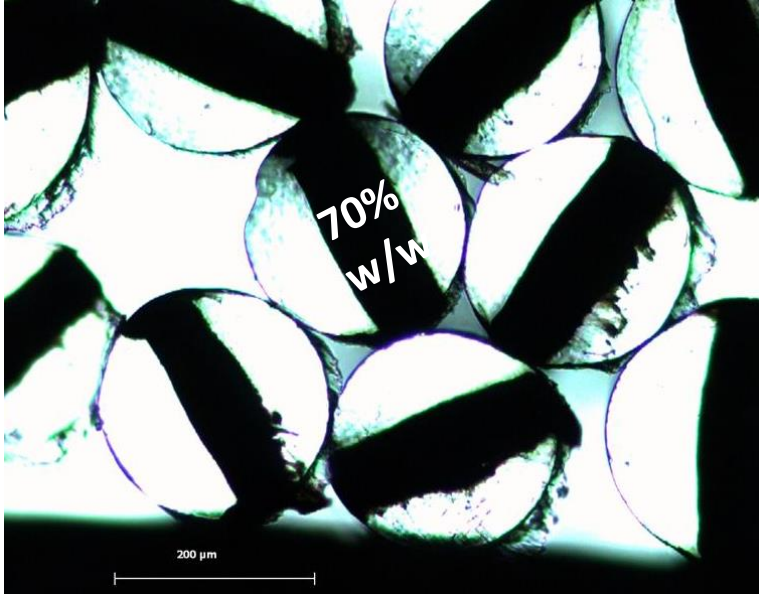
**70% CPC – max with a stable process**

**Elastomer (TPE)**

**Max. Draw ratio: 4,3**



# Samples



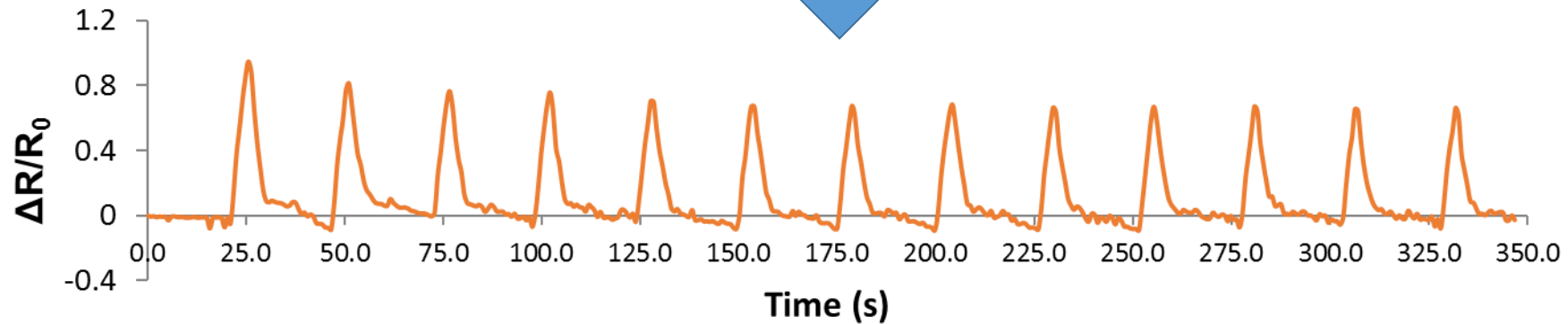
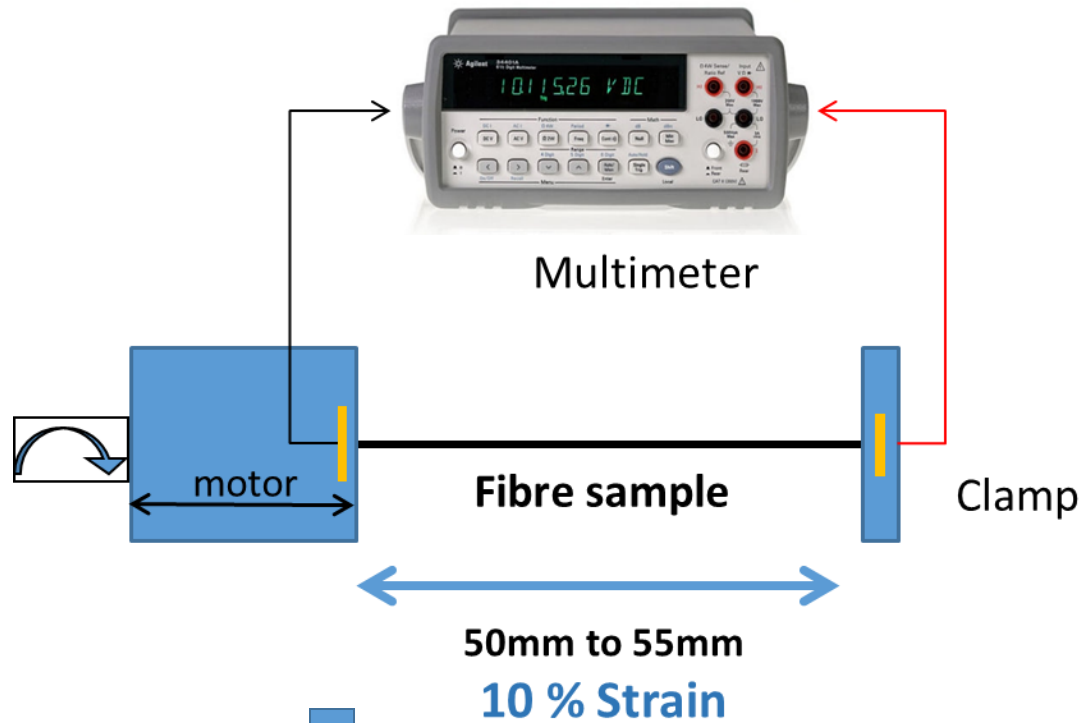
- **2 Side-by-Side conductive fibres**
- **70% CPC**
- **3000dtex / 36 filaments**

Sample	Polymer	Draw ratio
1	Elastomer	R4,3
2	Elastomer	R3,3



# Measurements

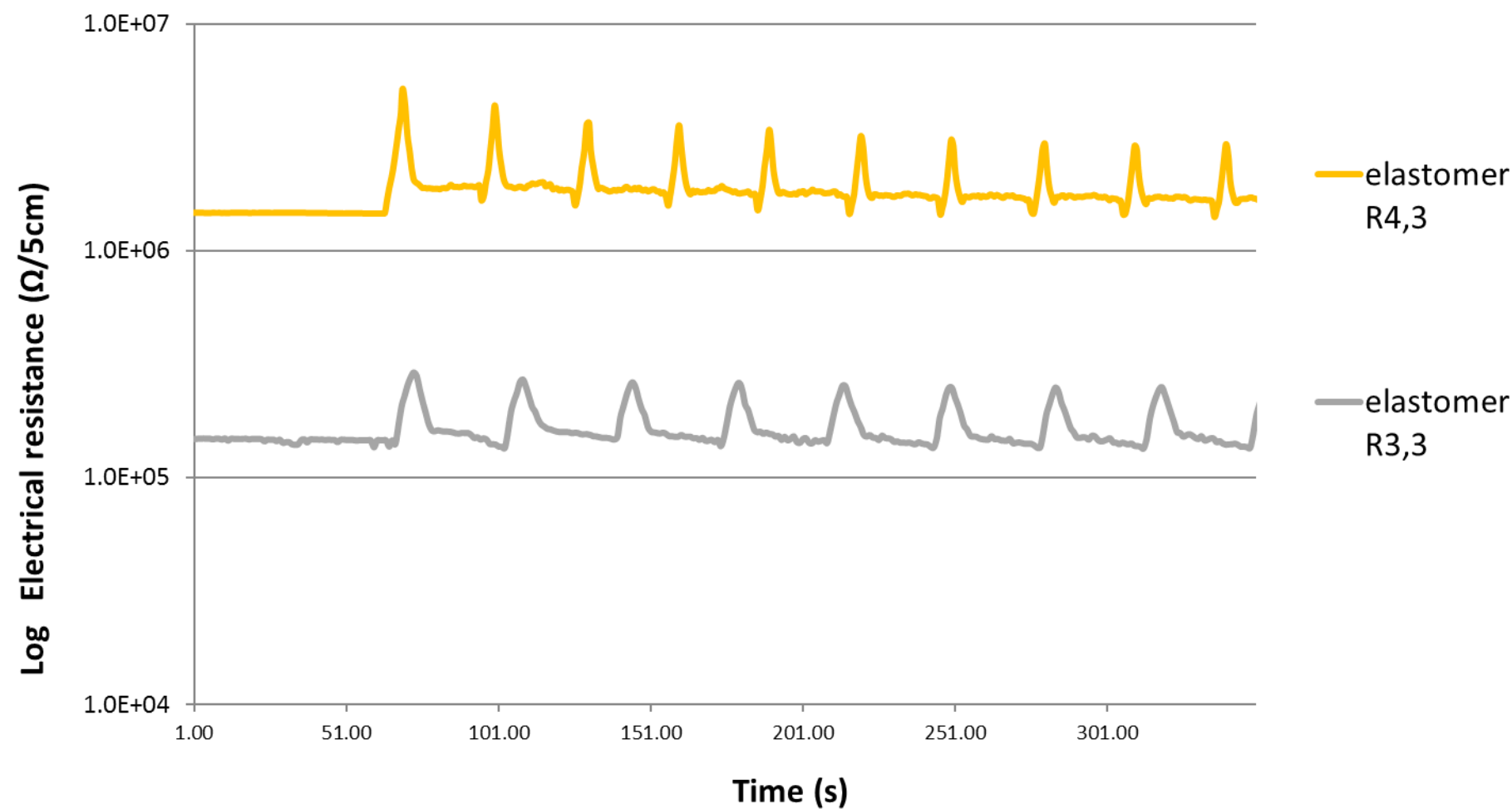
**Electrical resistance  
measurement  
under  
Cyclic strain**





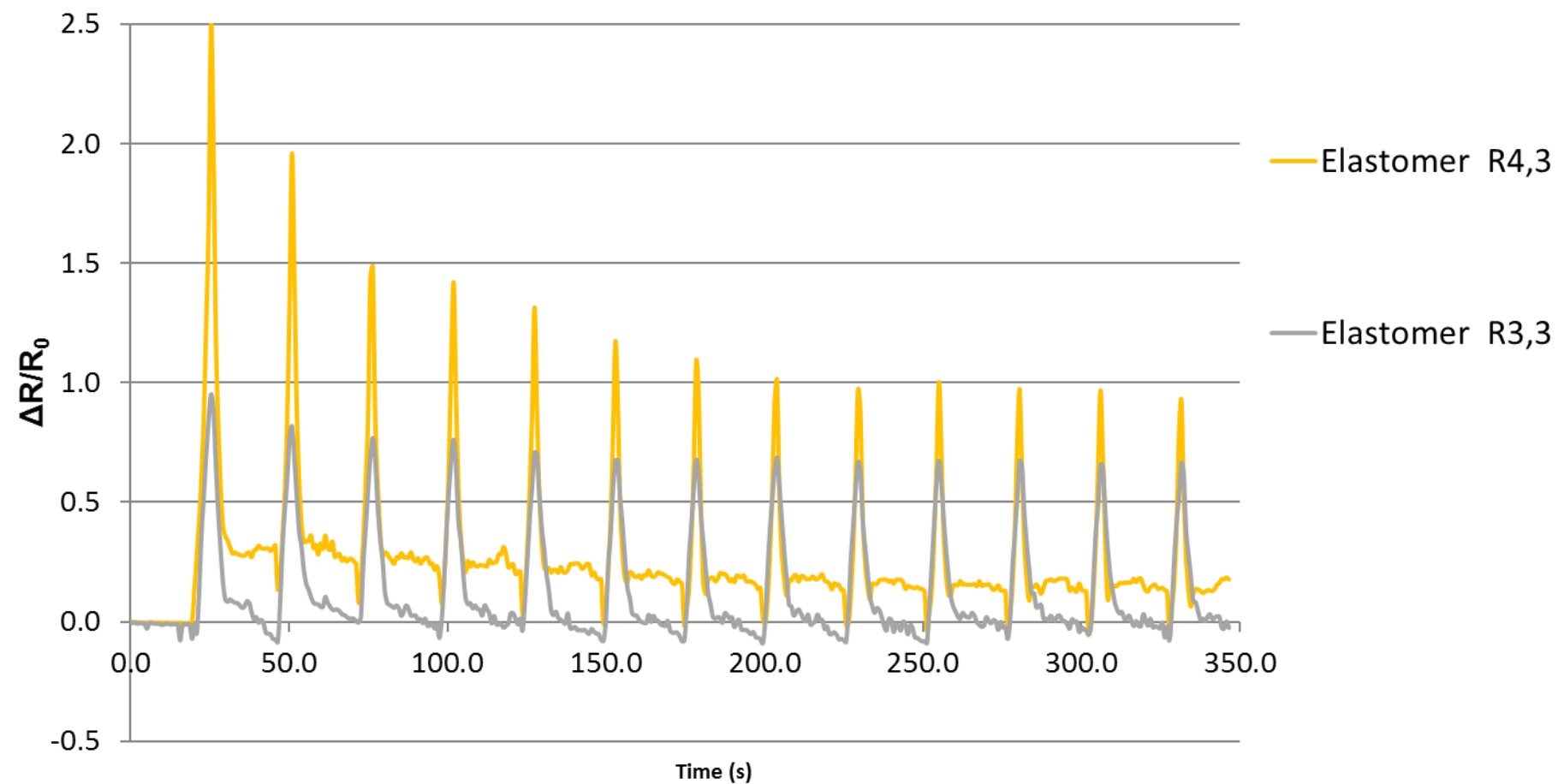


## Electrical resistance under cyclic strain



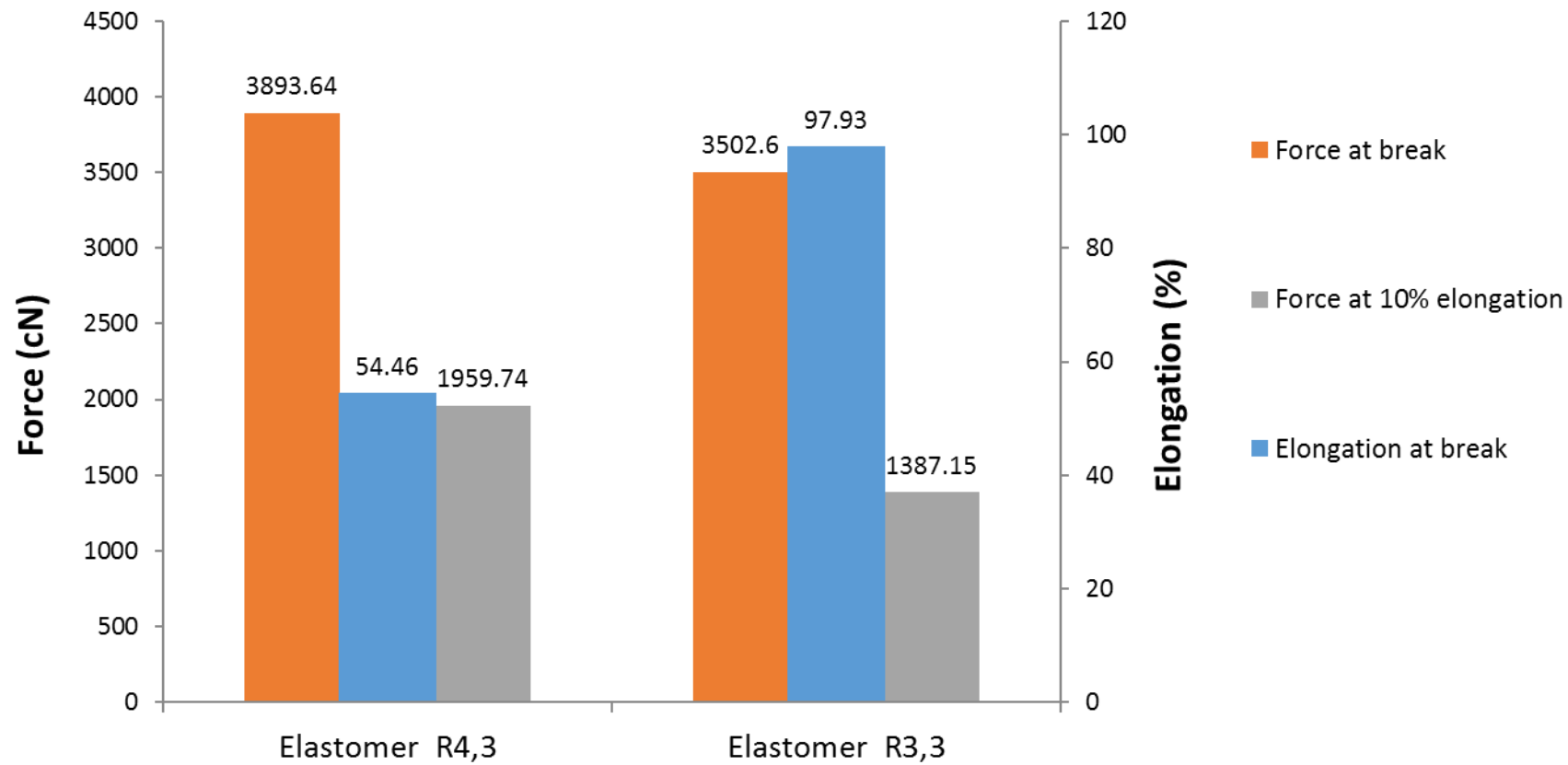


## Increase ratio of Electrical resistance under cyclic strain





# Mechanical Results



# Results

The filaments shows a clear electrical signal during elongation.

Higher amplitude of response for higher draw ratio

The higher the draw ratio, the higher the hysteresis observed on first cycles

Both produced fibres are able to be integrated on textiles structures as fully integrated sensors.



Other Sensor Fibres

Energy harvest Fibres

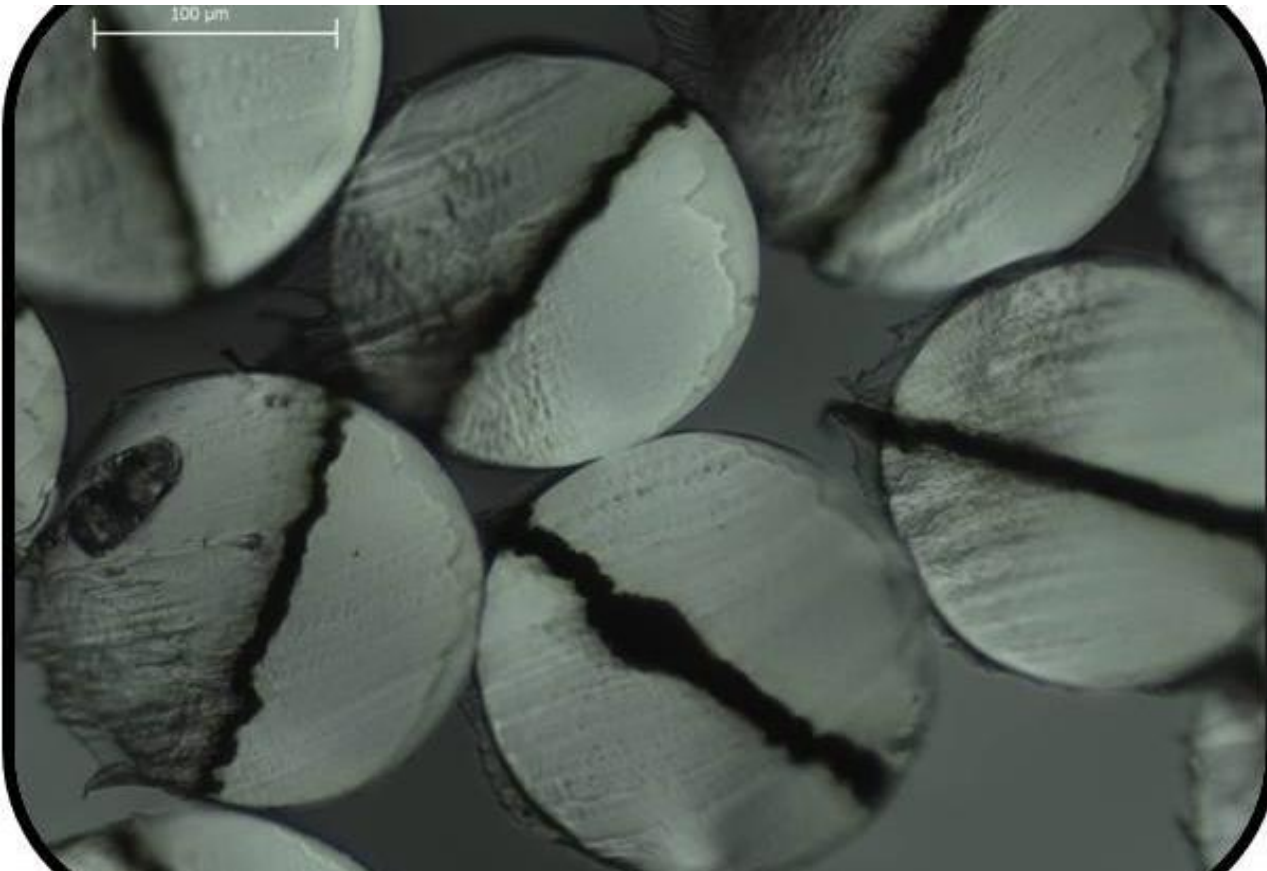
Energy storage Fibres

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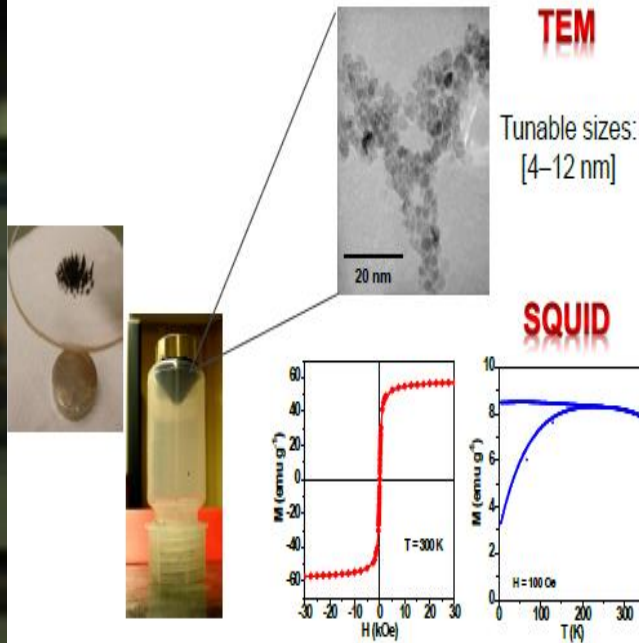
# Temperature sensing fibres



- ① Nanostructured polymer-based conductive fibres
- ① Tri-component multi-filament yarns for textiles using Conductive Polymeric Compounds
  - ① Side-by-Side cross section
  - ① PP / Polycaprolactone
  - ① MWCNT / PP



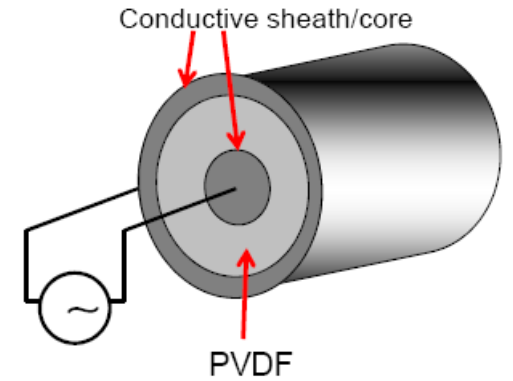
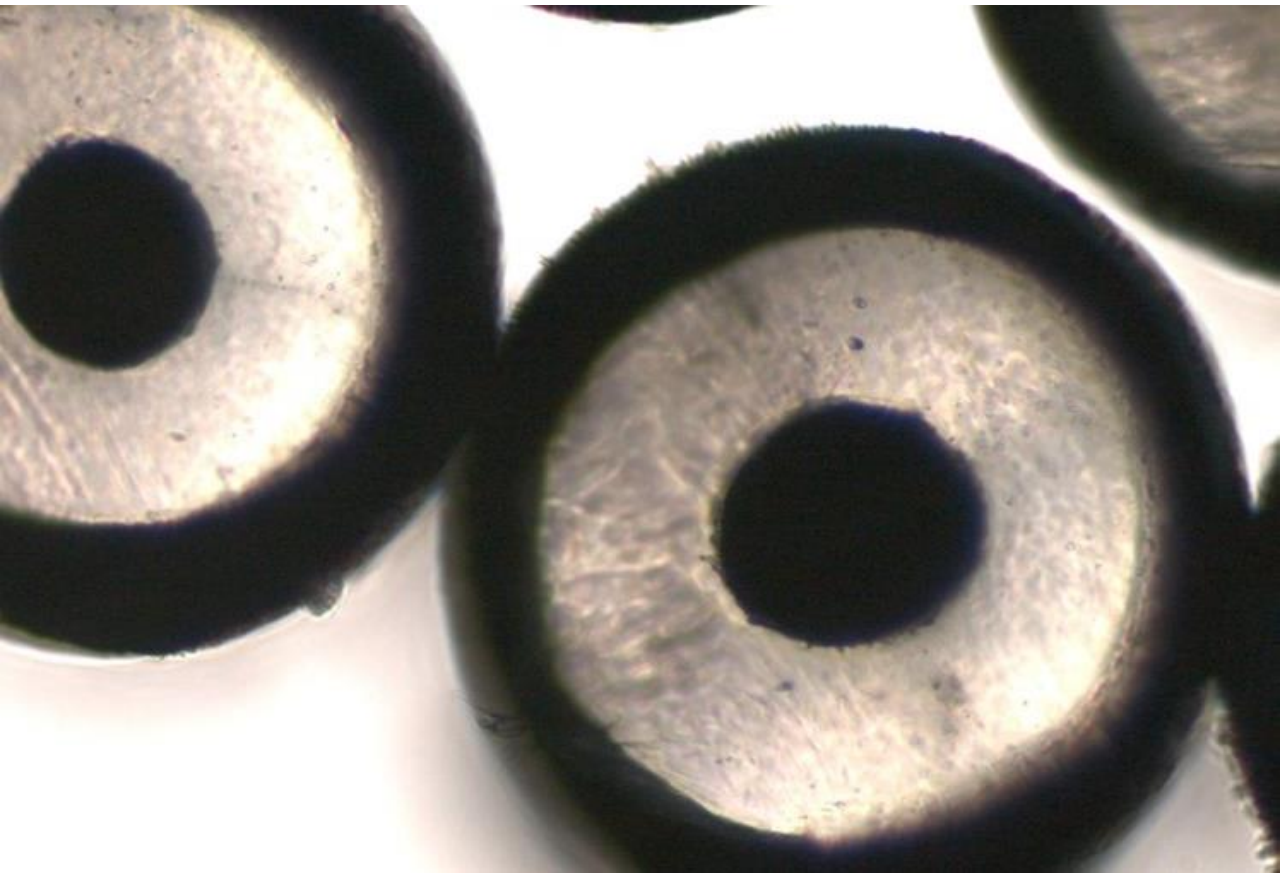
# Magnetic fibres



- ① Synthesis of magnetic nanoparticles
- ① Master-batch compounding
- ① Fibre spinning



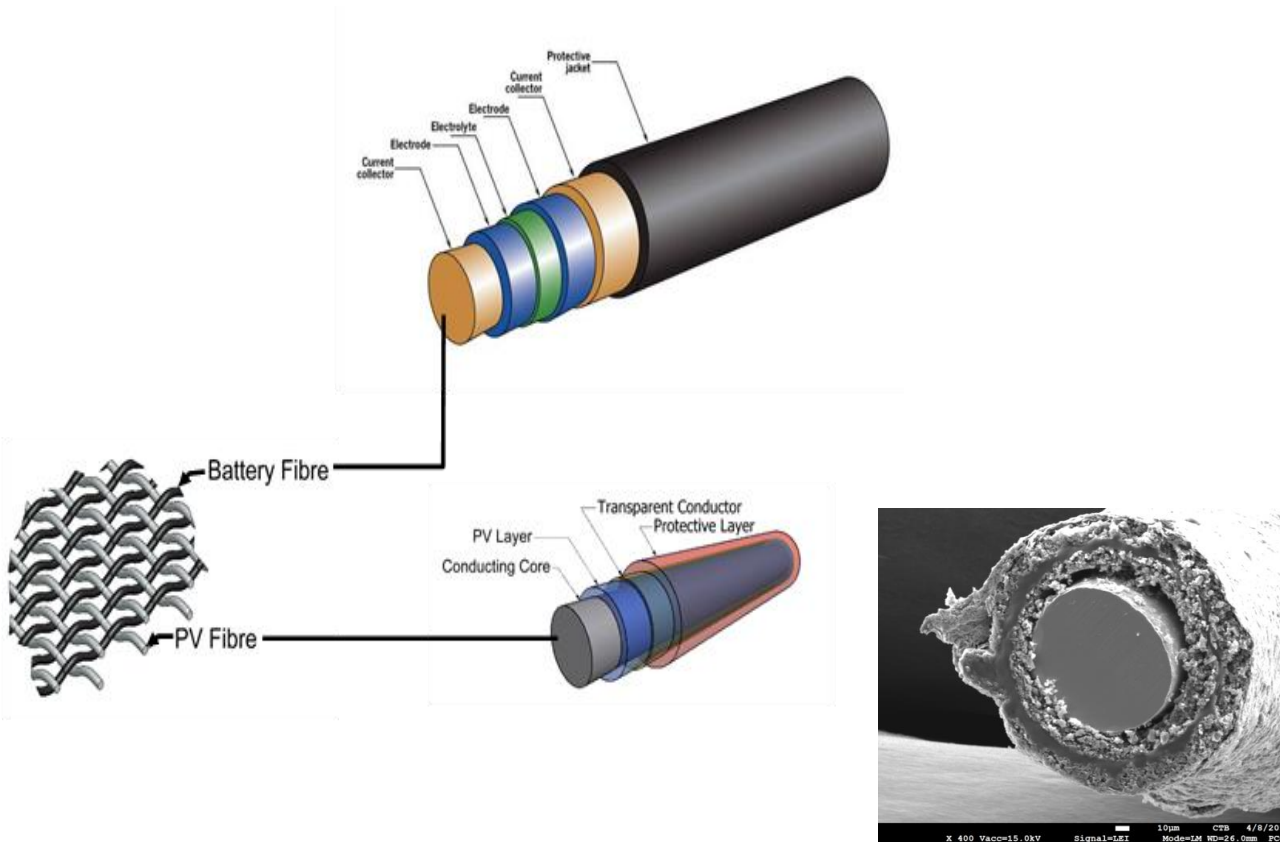
# Piezoelectric Fibres



① Tri-component piezoelectric fibres for sensor and energy harvesting



# Powerweave



① Photovoltaic energy harvesting fibres and

① energy storage fibres (battery)

① integrated by weaving or knitting processes



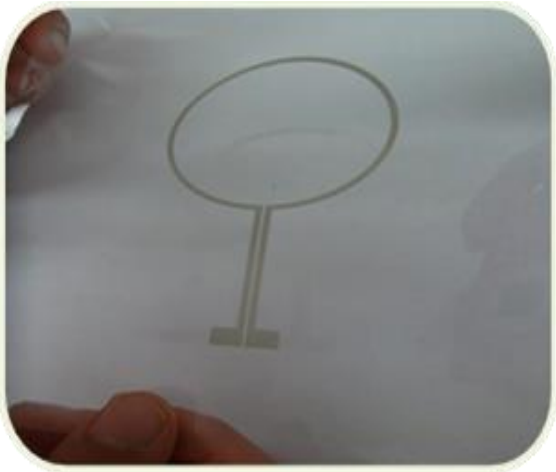


# Printed Sensors

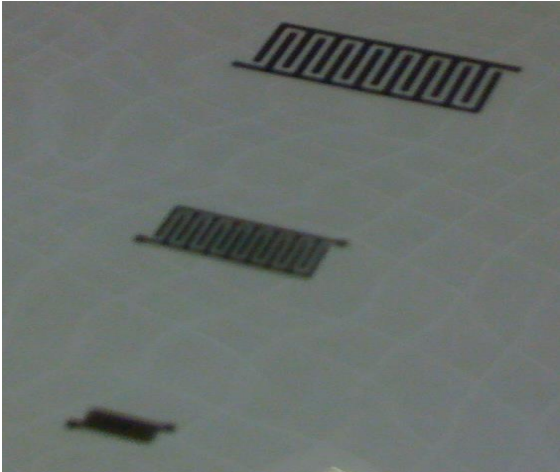
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Printed capacitive sensors



Printed Biosensors



Printed capacitive sensors

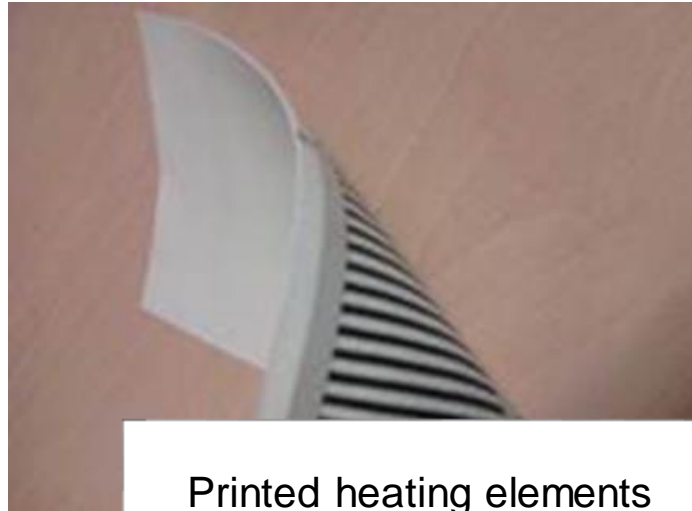


Printed Flexible Sensor / Actuator

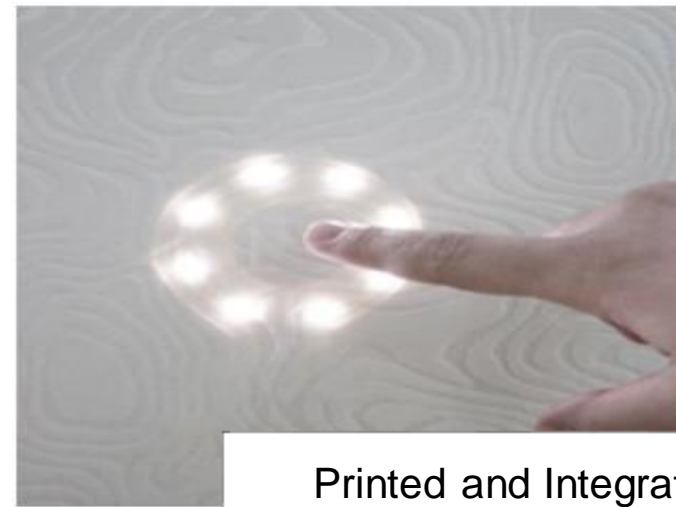




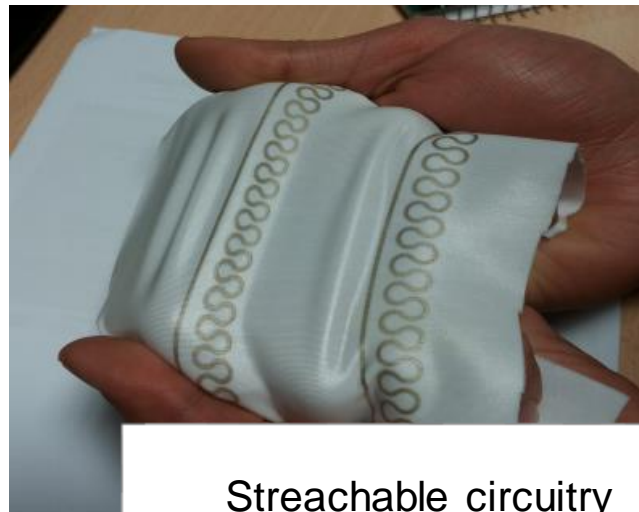
# Printed Electronics



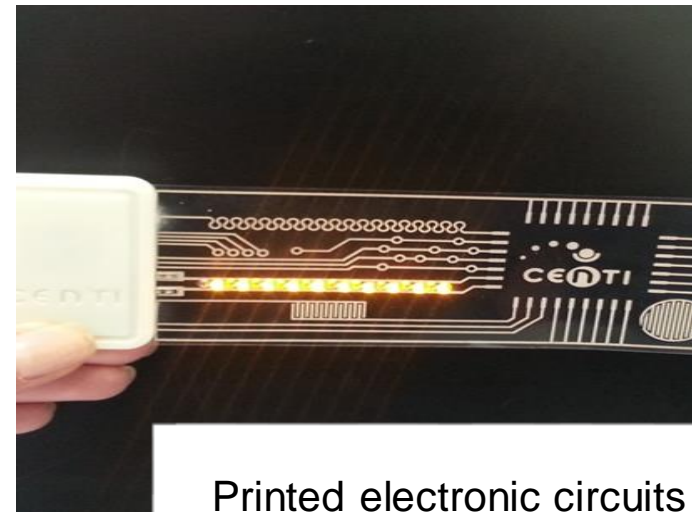
Printed heating elements



Printed and Integrated  
Lighting Device



Stretchable circuitry



Printed electronic circuits

# Full textile integration



- ① Printed sensor and light emission elements on textile for automotive applications





## Ongoing Developments

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# 1-D Neon



**F-SE**  
Fibre Stretchable Electrode



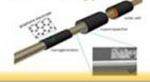
**F-FET**  
Fibre Transistor



**F-LED**  
Fibre Light-emitting Diode



**F-Energy**  
Fibre Energy Device



**F-Sensor**  
Fibre Sensor Device



① Development of fibre-based smart materials with integrated technology platform for manufacturing new products with applications in consumer electronics, energy, healthcare and fitness, smart buildings, sensors and e-skin for soft robotics.



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relats

SOLVAY  
asking more from chemistry®

Henkel

LG

European Commission

BIOAGE

PHILIPS





# CeNTI: Intelligent Technologies Designed for You

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Thank you for you attention

Braz Costa

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