Smart Textiles meet Organic Electronics
Commercialization Cluster of Organic and Large Area Electronics
<table>
<thead>
<tr>
<th>Time</th>
<th>Event</th>
<th>Speaker(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>9.00</td>
<td>Registration</td>
<td></td>
</tr>
<tr>
<td>9.15</td>
<td>“Introduciton to smart textiles”</td>
<td>(Carla Hertleer, UGent, B)</td>
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<tr>
<td>10.30</td>
<td>“TriTex e-learning course”</td>
<td>(Cédric Cochrane, ENSAIT, F)</td>
</tr>
<tr>
<td>10.45</td>
<td>Coffee Break</td>
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</tr>
<tr>
<td>11.00</td>
<td>“Stretchable electronics for smart textiles”</td>
<td>(Jan Vanfleteren, CMST, Imec, B)</td>
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<tr>
<td>12.00</td>
<td>Sandwich lunch</td>
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<tr>
<td>13.15</td>
<td>“Conjugated polymers: Versatile conductors and semi-conductors for electronic applications”</td>
<td>(Dirk Vanderzande, Uhasselt, Imec, B)</td>
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<tr>
<td>14.45</td>
<td>Coffee break</td>
<td></td>
</tr>
<tr>
<td>15.00</td>
<td>Discussion round</td>
<td></td>
</tr>
<tr>
<td>16.30</td>
<td>Closing</td>
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</tr>
</tbody>
</table>
Why smart textiles?
A wearable smart textile system comprises

• Sensors
• Actuators
• Data processing unit
• Communication system
• Energy supply
• Interconnections
Smart textiles

Embedded electronics

Wearable electronics

Interactive clothing

e-textiles

Intelligent textiles

SFIT

Smart Fabrics Interactive Textiles

Smart suit

Wearable textile systems
A combination of materials and processes

<table>
<thead>
<tr>
<th>Materials</th>
<th>Processes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conductive</td>
<td>Spinning</td>
</tr>
<tr>
<td>Optical</td>
<td>Weaving</td>
</tr>
<tr>
<td>Chromic</td>
<td>Knitting</td>
</tr>
<tr>
<td>Shape memory</td>
<td>Embroidery</td>
</tr>
<tr>
<td>Piezo</td>
<td>Laminating</td>
</tr>
<tr>
<td>Phase change</td>
<td>Others</td>
</tr>
</tbody>
</table>
Functional materials
Smart use of passive materials
Conductive materials

- carbon, metal, polymers
- conductive, semiconductive, dielectric properties

Kevlar coated with polypyrrol, copper, gold
Deposition of polypyrrole

- Monomer + Oxidant → Polymer
- Polymerization solution containing monomer & oxidant
- Layer of conductive polymer

Sample

Pd seeds

PPy coating

Para-aramid fibre
Electroless deposition of copper
Deposition of gold: exchange with copper
Adding conductive nanoparticles

- Conductivity
- Conductivity that changes with fibre expansion:
  - Deformation
  - Swelling
Obtaining elastic conductivity

Yarn level
Fabric level: Knitting, special weaving
Stretchable electronics
Smart yarns: elastic, conductive (A. Schwarz)
Hollow spindle process

- Drafting unit
- Elastic core yarn
- Upper hollow spindle carrying winding yarn
- Single covered yarn
- Lower hollow spindle carrying winding yarn
- Double covered yarn (S- and Z-direction)
- Delivery rollers

Smart Textiles meet Organic Electronics
Printing with conductive inks on textiles (I. Kazani)

- Digital or screen
- Homogeneity
- Accuracy of paths
- Washing
- Deformation
- Adhesion
Conductive inks on textiles

Smart Textiles meet Organic Electronics
Decline due to washing

- Table and graphs showing resistance changes before and after washing for different materials.
Smart Textiles meet Organic Electronics

Connections

Antenna

Power supply

Heating
Incompatibility of materials

\[ \varepsilon = 0 \]

\[ \varepsilon = 6.0\% \]

PU with copper coating

knitted fabric with stainless steel yarns

\(\frac{(R-R_0)}{R_0} \) vs strain

from experiment

from change in dimension
Sensors

Communication
Sensor
Data Processing
Interconnection
Powering
Actuator

Smart Textiles meet Organic Electronics
<table>
<thead>
<tr>
<th>Body</th>
<th>Environment</th>
<th>Textile itself</th>
</tr>
</thead>
<tbody>
<tr>
<td>biopotential</td>
<td>temperature</td>
<td>temperature</td>
</tr>
<tr>
<td>temperature</td>
<td>movements</td>
<td>wetness</td>
</tr>
<tr>
<td>respiration</td>
<td>biological</td>
<td>stretch</td>
</tr>
<tr>
<td>movements</td>
<td>chemical</td>
<td>wear</td>
</tr>
<tr>
<td>position</td>
<td>EM/ES fields</td>
<td>abrasion</td>
</tr>
<tr>
<td>sweat</td>
<td>water/moisture</td>
<td></td>
</tr>
<tr>
<td>odour</td>
<td>radiation</td>
<td></td>
</tr>
<tr>
<td>electrical</td>
<td>position</td>
<td></td>
</tr>
<tr>
<td>chemical</td>
<td>pressure</td>
<td></td>
</tr>
<tr>
<td>biological</td>
<td>sound</td>
<td></td>
</tr>
<tr>
<td>pressure</td>
<td></td>
<td></td>
</tr>
<tr>
<td>acoustic</td>
<td></td>
<td></td>
</tr>
<tr>
<td>skin properties</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Knitted electroconductive yarns as sensor

(a) Inductance variation as a function of respiration

(b) Resistance variation as a function of respiration
Woven pressure sensor, capacity based
Complex textile structures can add functionality
Smart fabrics: knitting

- Electrodes for electrostimulation
- Connection electrodes-contacts
- Textile compatible contacts
Contactless sensor EMG
Electrode electrostimulation
Textrodes

Smart Textiles meet Organic Electronics
Actuators
Actuators

<table>
<thead>
<tr>
<th>Category</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mechanical</td>
<td>shape memory materials, pH- and thermo-responsive polymers, electro-active polymers</td>
</tr>
<tr>
<td>Chemical</td>
<td>micro/nano capsules, cyclodextrines, gel based systems</td>
</tr>
<tr>
<td>Thermal</td>
<td>phase change materials, electroconductive fibres, Peltier textiles</td>
</tr>
<tr>
<td>Optical</td>
<td>electrochromic materials, (in)organic LED (OLED)</td>
</tr>
<tr>
<td>Acoustic</td>
<td>piezo electric materials</td>
</tr>
<tr>
<td>Electrical</td>
<td>electrostimulation</td>
</tr>
</tbody>
</table>
OLED

Textile structure
Organic materials
Image quality
Yield still low
Oxidation

Smart Textiles meet Organic Electronics
Energy supply
Energy classification

**Generation:**
- Thermal: Seebeck textiles, Peltier elements,
- Kinetic: piezo electric fibres,
- Radiation: photovoltaic fibres,
- Magnetic,
- Chemical: batteries,
- Fuel cells.

**Storage:** electrochemical (flexible batteries), electrical (super capacitor fibres)
A flexible battery
Flexible photovoltaics in garments
Photovoltaics: Dephotex

Organic photovoltaics
Nanostructures
Dyestuffs
Challenges:
• Materials
• Production
• Stability
• Concept

Transparent layer/Electrode
N semiconductor
P semiconductor
Electrode
Energy from motion: piezo electrics

Deformation leads to E field
Needs large surface, no thickness
PVDF

Challenges:
• Materials
• Concepts
• Production (poling)
Energy from heat: Seebeck effect

Materials:
• P semiconductor
• N semiconductor
• Conductive materials

Infineon demonstrator
Communication
Communication

Wired-wireless
Short-long distance
Visual-Auditive-Tactile
A selection of the prototypes for integration
Into clothing

Into protective clothing
Data processing
Electronics are required

- rigid PCBs
- flexible PCBs
- stretchable PCBs
- textile electronics
Smart Textiles meet Organic Electronics

MICAS van KULeuven  CSEM voor Proetex  Fraunhofer, Berlin
Textile electronics through weaving (Sefar)
Fibre transistor (L. Rambausek)

OFET: organic field effect transistor

Conductive core: gate
Insulating coating
Semiconductor coating
Electrode: source
Electrode: drain
Fibre OFET production

- Dip coating
  - thin layer
  - controlled crystallinity
  - homogeneous coating
- Vapour deposition
  - Controlled distance of electrodes
OFET stability

- Characteristics change
  - Pressure
  - Bending
  - Sensor
- Oxydation of semi conductor
OFET textile integration

Weaving structure
Right patterns
Right contacts
No false contacts
Stable contacts
Interconnections

Communication
Sensor
Data Processing
Interconnection
Powering
Actuator
Embroidery
Contacts (T. Linz)
Standardisation of smart textiles

TC 248 WG 31 definitions and framework of regulations

Standards electronics:
- no deformation, moisture, temperature
- manipulation of materials (clamping, deformation, …)

Textiles: no electronics
Conclusions

• Enormous possibilities
• Choice of materials, concepts, structures, production technologies
• Application oriented