ELECTROSPUN NANOFIBRES
NEW POTENTIALS AND CHALLENGES FOR TEXTILE MATERIALS

Karen DE CLERCK – Paul KIEKENS
karen.declerck@ugent.be

ETP CONFERENCE
25-26TH MARCH 2015
BRUSSELS, BELGIUM
Location
Ghent in Europe

- London: 310 km, 3h00
- Paris: 290 km, 2h00
- Amsterdam: 220 km, 2h20
- Brussels: 55 km, 0h35
- Berlin: 790 km, 7h45
The city of Ghent

Students: 
¼ of the city population
Technology Transfer at Ghent University

Technology transfer at Ghent University wants to facilitate the commercial application of promising technologies developed within the Ghent University Association. Key technology transfer activities include industrial collaboration programs, IP licensing and spin-off creation. For its liaison with industry, UGent uses a network of specialized business development centres backed by a Central Technology Transfer Office.
Nanofibrous nonwovens have unique characteristics

- Very small fibre diameters (< 500 nm)
- High specific surface area
- Small pore size
- High porosity

Nanofibres

1000x zoom

Human hair

20 µm
Nanofibres have various dedicated end-applications

- Filtration
- Energy
- Composites
- Sensors
- Protection
- Catalysis
- (Bio)medical
- Medical
- Bone Regeneration Implant
- Clean Air
Electrospinning (ES) in literature

Highlights:

- Electrospinning technology and modelling
- Novel polymer-solvent systems
- Advanced applications for nanofibres
Electrospinning technology @ UGent: solvent electrospinning

- High stability
- High reproducibility
- Fine fibres (nm-range)
- Use of solvents

Diagram showing:
- Voltage source
- Polymer reservoir
- Needle
- Taylor cone
- Nonwoven
- Collector
- Multi-nozzle
- Nozzle-less
- Polymer jet
- Polymer reservoir
- Rotating drum
- HV source
Principle of nozzle solvent electrospinning: a simple yet complex process

**Initiation:**
Formation of the Taylor cone

**Bending instability:**
Formation of the nanofibres by solvent evaporation, jet stretching and splitting
The electrospinning process is governed by a multitude of parameters

**Polymer solution parameters**
- Solvent (type, mixture)
- Polymer (concentration, MW)
- Viscosity, surface tension, electrical properties

**Processing conditions**
- Voltage
- Distance
- Flow rate
- Needle, collector

**Ambient parameters**
- Humidity
- Temperature
- Atmosphere

Stable process
Reproducible nanofibres
Upscaling
Production of nanofibre based media
- As rolled goods with or without substrate
- With grammage between 0.05 - 100 g m\(^{-2}\)
Waterfiltration

Composites

Biomedical applications

Optical monitoring: pH-sensors
Waterfiltration

Composites

Biomedical applications

Optical monitoring: pH-sensors
The ECM, the structural and biomedical support for cells, has a nanofibrous structure.
Electrospun nanofibres are the ideal candidate to mimic the ECM in biomedical applications

The ECM, the structural and biomedical support for cells, has a nanofibrous structure

R. Sakthivel & Y. Zhao
Genetic Engineering & Biotech news (2010), 30 (16)
Cells are well-supported by nanofibrous scaffolds, making them suitable for cell cultures.
Infiltration of cells into the scaffold is important: scaffold design needs to be adapted
Repair of tissues, including bone, cartilage, tendon, muscle, ligament, meniscus.
The importance of fibre alignment in tendon/ligament-to-bone repairs
Tubular grafts make repairing of nerves and arteries possible

J. Xie et al. Nanoscale (2010) 2, 35-44
Materials for wound dressings: a wide variety and an important choice

**Natural polymers**
- Better interaction with cells
- Low immunogenicity
- Collagen / gelatin
- Chitosan
- Silk

**Synthetic polymers**
- Mechanical properties
- Tailorable biodegradation
- Easy processing
- Synthetic polyesters (PGA, PLA, PCL)
- Polyurethane
- Polyvinyl alcohol

Combining them takes advantage of the best of both worlds
Drug delivery using nanofibres: several production methods and materials available, making tailored release possible.

There are several possible production methods and materials available, making tailored release possible.
Waterfiltration

Biomedical applications

Composites

Optical monitoring: pH-sensors
pH sensors

First signal or warning

Application in wound dressings, protective clothing, ….
Various combinations of pH-indicators and textile fibres are promising.

<table>
<thead>
<tr>
<th>pH-indicator</th>
<th>cotton</th>
<th>polyamide</th>
</tr>
</thead>
<tbody>
<tr>
<td>Xylenol Blue</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Cresol Red</td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Methyl Orange</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Ethyl Orange</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Congo Red</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Alizarin Red</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Methyl Red</td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>P-Rosolic Acid</td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Bromocresol Purple</td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Alizarin</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Nitrazine Yellow</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Bromothymol Blue</td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Brilliant Yellow</td>
<td>✓ **</td>
<td>✓</td>
</tr>
<tr>
<td>Neutral Red</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Phenol Red</td>
<td></td>
<td>✓</td>
</tr>
</tbody>
</table>

Dyes applied through conventional dyeing technique

Van der Schueren et al.
Text Res J 80 (2010) 590

✓ acceptable dyeing performance

clear halochromic sensitivity
Production and analysis of nanofibres functionalised with a pH-sensitive dye

**Influence on the electrospinning process**

**Colour change with pH**

- **pH 0**: Reversible Quick response time
- **pH 1**: Colour change

**Minimising dye migration**

- Use of a complexing agent
  - Faster response time
  - Minimal dye leaching
- Use of functionalised polymers

![PA6](image1.png)

![PA6/DR1-A](image2.png)
Halochromic PCL/chitosan nanofibres show potential for wound dressing applications

Dagarville et al.
Biosens Bioelectron 41 (2013) 30

- Biocompatible
- Antibacterial
- Stimulation of wound healing
- Monitoring of pH: indication on - healing stage - infections

Van der Schueren et al.
Waterfiltration

Composites

Optical monitoring: pH-sensors

Biomedical applications
High potential for water filtration

Same filter surface, high porosity, higher flux

High potential for water filtration

- Conventional membrane
- Microfibre membrane
- Nanofibre membrane

2 000 l/m³.h.bar ↔ 20 000 l/m³.h.bar
Effluent microfiltration

Secondary effluent is often discharged into surface waters, while there is an increased interest in water reuse.

Removal after filtration with nanofibres:
- 69% turbidity
- 76% biological activity
- 44% humic acids

High-flux filtration technique for effluent recuperation.
Functionalisation of nanofibres

Post-functionalisation

Inline functionalisation

Daels N. et al
Functionalisation with biocides/active nanoparticles

Bacteria

Nanofibre membrane

Lab scale filtration set-up

log10 removal (CFU/100ml)

non-functionalised PA-6

5 omf% WSCP functionalised

Functionalisation

Microfiltration

Biomedical applications

Waterfiltration

Composites

Optical monitoring: pH-sensors
“Delamination is the most frequently encountered type of damage occurring in composites during service.”

S.W. Tsai
1. Producing nanofibrous webs
2. Interleaving composite laminates
3. Testing for mechanical properties
A whole range of polymers can be electrospun into nanofibrous webs

Freedom to choose whatever properties you like, e.g. Young’s modulus

Matrix epoxy resin

Polyamide

Polycaprolactone

Polyurethanes, rubbers, ...
PCL nanofibres double the Mode I interlaminar fracture toughness

De Schoenmaker et al. Polymer Testing (2013), 32(8), 1495-1501
Nanofibres can bridge cracks and absorb energy

**A**

without nanofibres

**B**

with nanofibres
Waterfiltration

Biomedical applications

Composites

Optical monitoring: pH-sensors
COST Action MP1206

Electrospun nanofibres for bio-inspired composite materials and innovative industrial applications

Participating Countries: 33

Country of proposer/chair: red

Participating countries: blue
THANK YOU

Karen DE CLERCK – Paul KIEKENS
karen.declerck@ugent.be
Textile Research & Innovation in Europe from 2005 to 2025

10th Annual Textile ETP Conference, 25-26 March 2015, Brussels

www.textile-platform.eu
## Conference Programme

**Day 1 – 25 March 2015**

<table>
<thead>
<tr>
<th>Time</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>10.30–11.00</td>
<td>Registration and welcome coffee</td>
</tr>
</tbody>
</table>
| 11.00–12.30 | **Opening session: Textile Research & Innovation for a Better Europe**  
Session chair: Jacques Tankéré, Textile ETP Vice-President  
• Opening keynote by Clara de la Torre, European Commission, DG Research and Innovation  
• European Textile Research and Innovation - from 2005 to 2025, Paolo Canonico, Textile ETP President  
• Research on Emerging Textile Technologies – the role and strategies of Europe's Universities for Textiles, Dominique Adolphe, President of AUTEX  
• Applied Textile Research – the role and strategies of Europe's Textile Research and Technology Organisations, Braz Costa, President of TEXTRANET |
| 12.30–13.45 | Networking lunch                                                                                                                    |
| 13.45–15.30 | **Textile Materials of the Future – sustainability & functionality**  
Session chair: Emanuele Pivotto, Sinterama, Textile ETP Board Member  
• Sustainable fibre innovation, Robert van de Kerkhof, Lenzing AG, Austria  
• Bio-polymer based fibres & biofunctional coatings, Luc Ruys, Centexbel, Belgium  
• Nanofibres and electrospinning – a new frontier for textile materials, Karen De Clerck, Ghent University, Belgium  
• Electroactive textiles with fibers for sensing, energy harvesting and heating, Bengt Hagstrom, Swerea, Sweden  
• From wired clothing to real printed electronics on textiles, João Gomes, CeNTI, Portugal |
| 15.30-16.00 | Coffee break                                                                                                                       |
| 16.00–17.45 | **Textile Materials of the Future – high-performance and new applications**  
Session chair: Mustafa Denizer, Diktas, Textile ETP Board Member  
• Market trends in carbon and other high-performance fibre based materials, Hendrik van Delden, Gherzi, Switzerland  
• Textile reinforced buildings and infrastructures – the future of construction, Matthias Tietze, TU Dresden, Germany  
• Textile-based medical materials and devices, Erhard Mueller, ITV Denkendorf Produktservice GmbH & Michael Doser, ITV Denkendorf, Germany  
• Innovative technical textiles for off-shore bio-mass production, Joost Wille, Sioen Industries, Belgium  
• Potential of warp-knitted technical textiles for wound dressings, composites and agricultural applications, Nadège Boucard, MDB Texinov, France |
| 17.45–18.30 | **Formal General Assembly – for full and associated (premium & standard level) ETP members only**                                 |
| 19.00–21.00 | Networking dinner                                                                                                                  |
Day 2 – 26 March 2015

9.00 – 10.45  **Textile Manufacturing Technologies of the Future**  
Session chair: Michael Kamm, Sympatex, Textile ETP Board Member  
• A new world of textile functionalisation, Marc Van Parys, Unitex, Belgium  
• Textile biotechnology, Jan Marek, Inotex, Czech Republic  
• Manufacturing of technical textiles in 3D, Dominique Maes, Van de Wiele, Belgium  
• New technology developments in non-woven production and advanced non-wovens from recycled carbon fibres, Petra Franitza, Saxon Textile Research Centre STFI, Germany  
• Will 3D Printing also revolutionise the textile industry?, Ger Brinks, Saxion University of Applied Sciences, The Netherlands  

10.45 – 11.15  Coffee break

11.15 – 13.00  **The Textile and Fashion Industry of the Future and its New Business Models**  
Session chair: Pierre Van Trimpont, TIC, Textile ETP Board Member  
• ManuTex 4.0 - the future of textile manufacturing, Yves Gloy, ITA RWTH Aachen, Germany  
• The SpeedFactory, Gerd Manz, Adidas AG, Germany  
• Digitalising the Fashion Industry, Philippe Ribera, Lectra, France  
• Collaborating creative value chains for textiles and fashion, Meike Tilebein, DITF-MR, Germany  
• New business models for personalised fashion products, Michel Byvoet, Bivolino.com, Belgium  

13.00 - 14.00  **Networking Lunch**

14.00-15.30  **Closing session: The Textile & Clothing Industry in an European Industrial Renaissance – European and national strategies**  
Session chair: Francesco Marchi, EURATEX, Textile ETP Board Member  
• European policies for an Industrial Renaissance, Jean-François Aguinaga, European Commission - DG Internal Market, Industry, Entrepreneurship and SMEs  
• Euratex strategies for a competitive and innovative EU Textile and Clothing industry, Serge Piolat, Euratex  
• A strategic plan for the future of the French Textile and Clothing industry, Yves Dubief, Union des Industries Textiles, France  
• A new joint Technology Platform for the Italian Textile and Clothing industry, Aldo Tempesti, TexClubTec, Italy  
• The European Technology Platform – the next 10 years, Lutz Walter, Textile ETP
Practical Information

Venue
HUSA President Park Hotel, Blvd. du Roi Albert II, 44, B-1000 Brussels, www.husapresidentpark.com

Conference organiser
The European Technology Platform for the Future of Textiles and Clothing a.i.s.b.l., Brussels

Contacts
Agenda, sponsorships, communication
Lutz Walter
Ph. +32-2-285.48.85
lutz.walter@euratex.eu

Registration, invoicing, conference logistics
Paulette De Wilde
Ph. +32-2-285.48.83
paulette.de.wilde@euratex.eu

Conference Materials
All validly registered conference participants will receive hand-out documentation containing programme, participants list, speech abstracts and various other information materials.
Conference presentations will be made available electronically, subject to clearance by the speaker, within 2 weeks after the conference.

www.textile-platform.eu

The conference facilitates dissemination of results of collaborative research projects and is for this purpose supported by the following projects and organisations: