Carbon nanotubes in composites and coatings for smart textile applications

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Overview

CENTEXBEL – Belgian Textile Research Centre

- CNT in yarn extrusion
- CNT in textile coating
- Smart textiles
- Conclusions
Belgian Textile Research Centre

Activities and services of Centexbel

Testing

collective centre of expertise
• 800 Belgian textile producers
• 100 associated national and international companies

Certification

Brussels

Ghent

Verviers

Research

Consultancy
Belgian Textile Research Centre

Testing
- burning behaviour
- FR-properties
- flame propagation
- smoke density
- physical testing
- abrasion
- colour fastness
- antistatic properties
- chemical analysis
- hazardous substances
- extraction
- VOC determination
- microbiological analysis
- anti-microbial effect
- biodegradability
- barrier effects

Certification
- GuT
- Öko-Tex
- Made in Green
- CE-labelling
- CertiPUR

Consultancy ... and more
- patent cell
- in-company training
- technological consultancy
- standardisation
Incorporation of nanofunctionality in textile yarns

Challenge: bringing nanofunctionality to textiles...

Textiles = demanding applications

Requirements additives → yarn extrusion:

- durable effect
- compatible mechanical properties, low hardness
- small size, good dispersion, easy incorporation
Incorporation of nanofunctionality in textile yarns

Limitations of the currently used additives?

- size scale too large
- often insufficient thermostability
- negative influence on spinning ability and properties
- only limited contents possible = too low for properties

NANOCOMPOSITES OFFER NEW PERSPECTIVES in TEXTILE APPLICATIONS!
Incorporation of carbon nanotubes in textile yarns

Carbon nanotubes
- promising material for high electrical conductivity
- low concentrations needed
Incorporation of carbon nanotubes in textile yarns

The extent of property enhancement depends on many factors:
- aspect
- degree of dispersion
- orientation of the CNTs in the matrix
- adhesion at the CNT-matrix interface

Dispersion of nanofillers is more difficult than that of microfillers
→ strong tendency to agglomerate
→ Van der Waals interactions between individual tubes often lead to significant aggregation or agglomeration
→ due to the large surface area the nanoparticles tend to interact differently with the polymer matrix than the bulk materials
Carbon nanotubes in extrusion applications
PA6 and PP masterbatches (15 % CNTs)
→ twin screw compounder → compounds (different concentrations)
different temperature profiles were used in order to evaluate the influence of the compounding temperature
Optimization of the process is indispensable
- correlation between MVI and resistance measurements
- $10^3 - 10^4 \, \Omega$ – 5% CNTs
dispersion is still the bottleneck since the final properties will depend on the process that is used to disperse the CNTs and the affinity between the CNTs and the matrix

Yarn extrusion → strict requirements for dispersion (Particle size → aggregates should be smaller than 5 µm!)

- Diameter of the fibre – few micron
- Spinnability of the fibre – take-up speed 1000-2000m/min + drawing process (draw ratio PA6: 2.5, PP:3)
- Filter mess size – 10s micron
carbon nanotubes tends to align during drawing of the yarns → conductivity is lost
Non-stretched tape: $10^4$ Ω
5x stretched tape: $10^5$ Ω
10x stretched tape: $10^7$ Ω

Thermal annealing is needed

as extruded  solid state drawn  solid state drawn & annealed
Incorporation of carbon nanotubes in textile coatings

Research strategy

• step 1: combination of CNT with binders for textile coatings
• step 2: preparing coating formulations for application on textiles
• step 3: measuring the electrical conductivity
Incorporation of carbon nanotubes in textile coatings

Step 1: combining CNT with binders for textile coatings

Ready to use CNT
- nano powder
- CNT-dispersions – water-based
- CNT-dispersions in specific binders

Commercially available binders for textile coatings

Polyurethanes
- Impranil (Bayer)
- Lurapret (BASF)
- Edolan (Tanatex Chemicals)
- others

Acrylates
- Lurapret (BASF)
- Tubicoat (CHT)
- others

Arkema (FR)
Bayer (D)
Nanocyl (BE)

CNT-content
1% - 3% - 5%

solid-content
40% - 50% - 60%
Incorporation of carbon nanotubes in textile coatings

Step 1: combining CNT with binders for textile coatings

Dispersion methods
- high speed mixing
- ultrasonic dispersion

Experimental observations
- high dilution
  - 1 % CNT dispersion
  - 40% binder dispersion
- viscosity increase
  - CNT acts as a thickener

Evaluation of the compatibility
- microscopic observation
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**Step 1: combining CNT with binders for textile coatings**

Compatibility of CNT with coating binders

<table>
<thead>
<tr>
<th>Good compatibility</th>
<th>Not Compatible</th>
</tr>
</thead>
<tbody>
<tr>
<td>➔ CNT not visible</td>
<td>➔ aggregates of CNT-particles</td>
</tr>
<tr>
<td>➔ limited viscosity increase</td>
<td>➔ phase separation</td>
</tr>
<tr>
<td>➔ homogeneous solution</td>
<td>➔ turbidity</td>
</tr>
</tbody>
</table>

**No general rule**

- compatible with PU and acrylic dispersions
- depends on surfactants used in dispersions
Incorporation of carbon nanotubes in textile coatings

Step 2: preparing coating formulations for application on textiles

Acrylic based textile coating with gradual increased CNT concentration
- homogeneous dispersion
- limited viscosity increase
- CNT concentration from 0.25 wt% up to 15 wt% on dry binder

9% CNT – 1 layer of 0.1 mm wet

10% CNT – 2 layers of 0.2 mm wet
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Step 3: measuring the electrical conductivity

Acrylic based textile coating with gradual increased CNT concentration
- highly flexible textile coatings
- resistivity down to 60 Ω
- electrical conductivity starts at 4 wt% CNT
Smart textile applications

Integration of solar cells in textile

Conductive electrode
Sheet resistivity of 10 Ω/sq

Development of flexible solar cells for
- cloths
- tents and screens
- backpacks, ...
Smart textile applications

Flexible heating devices

Resistivity heating: different potentials give different temperatures

- heating layer on textile for clothing, car seats, technical devices, etc.
- no need for metal wires
- highly flexible
- easy integration in textiles
Smart textile applications

Integration of capacity switches in textiles

- push buttons in cloths
- sensors in mattresses, floor- and wallcoverings
Smart textile applications

Answers to societal megatrends?

**Energy**
- Raw materials
- Flexible solar panels for remote areas
- Replacement of metals in flexible electronics

**Ageing society**
- Sensors for monitoring health and safety
- In cloths, mattresses and floorcoverings
Conclusions

CNT in yarn extrusion

- Mixing of CNT in a polymeric matrix is not evident
- Knowledge and optimisation of the dispersion process is essential
- Conductivity level: kiloΩ

CNT in textile coatings

- CNT are compatible with binders for textile coatings
- High concentration of CNT in coatings is possible but difficult
- Conductivity level: anti-static down to 60 Ω

Smart textile applications

- CNT introduce electrical conductivity into yarns and coatings for textiles
- First concepts have been developed: textile heating, capacity switches