Sustainable flame retardancy for textiles and related materials based on nanoparticles substituting conventional chemicals (FLARETEX) MP1105
Start date: 23/05/2012
End date: 22/05/2016
Year: 2
Prof. Paul Kiekens
Chair
Ghent University, Belgium
Scientific context and objectives (1/2)

• **Background / Problem statement:**
  Many conventional flame retardants (FRs) still contain toxic chemicals. The challenge is to replace these with sustainable and environmentally friendly alternatives by coordinating the development of innovative FRs with low fire toxicity and environmental impacts and halogen-free FRs

• **Brief reminder of MoU objectives:**
  - To build a European multidisciplinary Knowledge Platform on Sustainable Flame Retardancy
  - To facilitate the rapid development and commercialisation of fire safe textiles and related materials of low toxicity and ecotoxicity, using available / novel technologies
  - To promote cooperation between researchers from different scientific disciplines
Background illustration

• Ca. 100,000 people annually die in fires
• Cost of fire is ~ 1% of GDP within EU
• Production volume: 2 million tonnes FRs (worldwide) (→ 0.5 million tonnes in EU)
• Almost 4 billion EURO
• Nearly 4% growth/year
• 40% are halogenated FRs

Recently, many halogenated FRs have been banned due to their toxicity to environment and human health → need to be replaced! (Source: Defra report - 2010)
Scientific context and objectives (2/2)

• Research directions:
  - Identification of safer alternatives to halogenated FRs
  - Development of new and sustainable nanobased FR systems for synthetic fibres/textiles
  - Analysis of their effectiveness, durability, (smoke) toxicity and particularly environmental impact (LCA)
  - Synergistic effect of nanomaterials with conventional FRs
  - Environmentally friendly surface treatment and application processes for FR
  - Explanation of the FR mechanism of action of nanostructured materials
  - Drawing up testing methods, standards and requirements

FLARETEX is the first organised multidisciplinary scientific and technology network on Sustainable Flame Retardancy
Working groups

1. **WG1 - Novel Flame Retardants (Prof. F. Branda, Dr. G. Malucelli, IT) :** new and environmentally friendly nanobased FR systems, synergistic effects derived from combining nanoparticles with conventional FRs and their potential effectiveness

2. **WG2 - Toxicological/environmental aspects (Dr. A. Stec, UK) :** FRs obtained in WG1 are investigated for their fire toxicity, ecotoxicological and environmental impacts (LCA)

3. **WG3 - Processing/Applications/Commercialisation (Dr. C. Pereira, PT) :** various application processes (e.g. plasma coating, spinning, sol-gel, …) are studied, developed and optimised

4. **WG4 - Testing/Standardisation (Dr. S. Gaan, CH) :** new test methods and performance standards will be developed
Results vs. Objectives

• **Objective A**: Identification of the safer alternative to halogenated and antimony based FRs
  Results – ex.: Replacement of traditional FRs in rigid polyurethane (PU) foams with intumescent FR; use of casein or hydrophobin coatings for improving the flame retardancy of cotton and polyester

• **Objective B**: Development of new and sustainable nanobased FR systems
  Results – ex.: Novel bicomponent fibres with nanoclay and/or a phosphorus FR introduced into the core or sheath of fibre were produced. The fibres with clay and FR in the sheath showed better FR and mechanical properties

• **Objective C**: Analysis of their effectiveness, durability, (smoke) toxicity and particularly environmental impact (LCA)
  Results – ex.: Novel Br/Sb-free FR system tested for textile finishing by coating (inorganic polyphosphate/ acrylic/polyurethane–based), exhaustion (cyclic polyphosphonates–based) and impregnation (THPS–based)

• **Objective D**: Improved surface treatment and application processes for FR
  Results – ex.: Novel green FR systems based on macromolecules through impregnation/exhaustion treatments and layer -by -layer (LbL) assemblies

• **Objective E**: Explanation of the FR mechanism of action of nanostructured materials
  Results – ex.: Fundamental understanding of the mechanism of action involving the use of LbL on cotton and on polyester fabrics

• **Objective F**: Drawing up of testing methods, performance standards and durability requirements for FR in different sectors
  Results – ex.: Combustion characterization of fabrics treated by novel flame retardant systems (biomacromolecules, e.g. proteins, DNA) with TGA and pyrolysis-combustion flow calorimeter (PCFC).

• **Objective G**: Study of the synergistic effect of combining nanomaterials with conventional FRs
  Results – ex.: Combination of biomacromolecules with nanoparticles

• **Objective H**: Scaling up and commercialisation
  Results – ex.: Three novel FR systems (coating, exhaustion and impregnation) have been verified in pilot-plant and small-scale industrial production
Results vs. Objectives

<table>
<thead>
<tr>
<th>Objective</th>
<th>1st year</th>
<th>2nd year</th>
<th>Total planned (over 4 years)</th>
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<td>Networking partners (individual participants)</td>
<td>280 (36 countries)</td>
<td>411 (35 countries)</td>
<td>60 (23 countries)</td>
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<tr>
<td>No. of industry participants</td>
<td>48</td>
<td>186</td>
<td>30</td>
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<tr>
<td>No. of STSM</td>
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<td>Joint projects initiated</td>
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Added value of networking:
- Multidisciplinary research across borders
- Results of all carried out STSMs and equipment and data exchange
- Preparation of joint publications and research proposals
Significant Highlights in Science and Networking (1/8)

- The use of nanoparticles for flame retardancy, including natural and hybrid nanoparticles
- The use of natural (= green) flame retardants
- The use of layer-by-layer (LbL) deposition and sol-gel technology
- Intumescent flame retardants as alternative for halogen based FRs
- Development of a modelling tool
- Improved surface treatment (UV, spray-drying micro-encapsulation, (atmospheric) plasma pre-treatment, …)
- The use of multifunctional (nano)chemicals combining flame retardancy with other properties
- Development of sampling methods for fire effluents which can harm the environment
- The correlation between semi- and volatile fire effluents and particulate distribution under different fire scenarios
The Latvian State Institute of Wood Chemistry developed rigid PU foam from renewable resources that was protected with thermally expandable intumescent mats from Technical Fibre Products Ltd (TFP).

Fig. 1. Heat release rate of rigid PU foams protected with different intumescent mats
Textile 1 – Technofire 60172A mat; Textile 2 – Technofire 60152C mat

Fig. 2. SEM image of rigid PU foam with intumescent glass fiber mat
Significant Highlights in Science and Networking (3/8)

- Improvements in flame retardancy of cotton and polyesters by using casein or hydrophobin coatings

Both these proteins, rich in phosphorus and sulphur, favour the formation of coherent char that limits the production of flammable volatile species


## Significant Highlights in Science and Networking (4/8)

### Burning time (s) | Burning rate (mm/s) | Residue (%)
--- | --- | ---
COT | 72 | 1.5 | -
COT_Cas | 100 | 1.0 | 34
COT_Hydr | 104 | 1.1 | 19

*COT treated with caseins*
Significant Highlights in Science and Networking (5/8)

Working group Dr. Klaus Opwis (DTNW, Krefeld, Germany)

- Synthesis of innovative polyphosphazenes as new non-halogenated flame retardants
- Photochemical immobilization on textiles
- Flame retardant properties
- High washing fastness

Excellent foam-forming properties!!!

Ally-oxy-PPZ

PET/CO 50/50
DIN 4102 - 1 - B2

blank  PPZ-modified
Nanocomposites in Synthetic Fibres: Bolton work

Bicomponent fibres

Optical microscopic image

SEM

Sheath: PA6
Core: PA6 / Al-Phos (10wt%)

Kandola, Horrocks et al, 2012
Nanocomposites in Synthetic Fibres: PA6 Bicomponent fibres

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PA6 = - ; Clay = 25A (2%); FR = Aluminium phosphinate (10%) .

Kandola, Horrocks et al, 2013
Significant Highlights in Science and Networking (8/8)

• COST MP1105 workshops within Fire Retardancy and Protection of Materials Conference (FRPM’13), Lille, FR, 3/06-4/07/2013: 225 participants

• Scientific workshop on “Multifunctional textiles based on hybrid coatings and nanoparticles, Naples, IT, 17/09/2013: 56 participants

• WG4 Standardisation meeting “Flame retardant textiles/textile composites: Legislative landscape, EU vs. member states”, Bolton, UK, 14-15/10/2013: 52 participants

• Training School “Flame Retardant Solutions for Fibre Reinforced Composites’, Porto, PT, 26-28/03/2014: 33 participants

• MC meeting + Joint COST MP1105 FLARETEX and FRT14 Conference with 1-day scientific workshop “Replacement of Halogenated Flame Retardants in Upholstered Furnishings”, Preston, UK, 14-17/04/2014: 191 participants

• Scientific workshop “Development of Flame retardants for the future”, Dübendorf, CH, 8/05/2014: 99 participants
Future Plans

- 16-18 September 2014, Warsaw, PL: E-MRS Fall 2014 Symposium M: "Functional textiles– from research and development to innovations and industrial uptake" in cooperation with COST MP1206 and 2BFUNTEX

- 7 October 2014, Dubrovnik, HR: Scientific workshop "Characterisation of flame retardant textile and related materials", linked to ITC&DC 2014 conference

- 20-23 October 2014, Bolton, UK: Training School "Advanced testing instruments"

- 27-29 January 2015, Tampere, FI: Joint WG1 meeting/2BFUNTEX MDT meeting on Flame Retardancy

- 4-6 February 2015, Madrid, ES: Workshop on “Advances in Flame Retardancy of Polymeric Materials” within AESP7 conference

- 26-27 March 2015, Bucharest, RO: Workshop on “Advances in the synthesis and characterization of nanomaterials for flame retardant applications”

- 28 April 2015, Montpellier, FR: 4th COST MP1105 MC meeting

- 29-30 April 2015, Montpellier, FR: Workshop on “Thermophysical properties, Thermal stability and Fire Retardancy of blends and filled polymers” within EUROFILLERS 2015 conference

- 6 STSM’s in year 3
Appendix

• The following three slides should be prepared for information only in case of questions from the DC but should NOT be presented
Action Parties

Grant Holder:
Ghent University
Ir. Els Van der Burght
Belgium

![Bar chart showing the number of parties and non-COST countries over years]
Action participants

Year 1
- Total no. of individual participants: 280
- Female: 110
- ESR: 45
- Industry: 48
- non-COST countries: 12

Year 2
- Total no. of individual participants: 411
- Female: 139
- ESR: 70
- Industry: 186
- non-COST countries: 20
# Use of COST Instruments

<table>
<thead>
<tr>
<th>Activity (No.)</th>
<th>Year 1</th>
<th>Year 2</th>
<th>Year 3 (planned)</th>
<th>Year 4</th>
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<tr>
<td>STSMs</td>
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<tr>
<td>Training Schools</td>
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<tr>
<td>Workshops or Conferences</td>
<td>4</td>
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  (incl. STSM reports)   |        |        |
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