Composite Materials Group

Department of Materials Engineering
KU Leuven

www.composites-kuleuven.be

Composite Materials Group

2017, personnel: 50

6 leaders of research directions

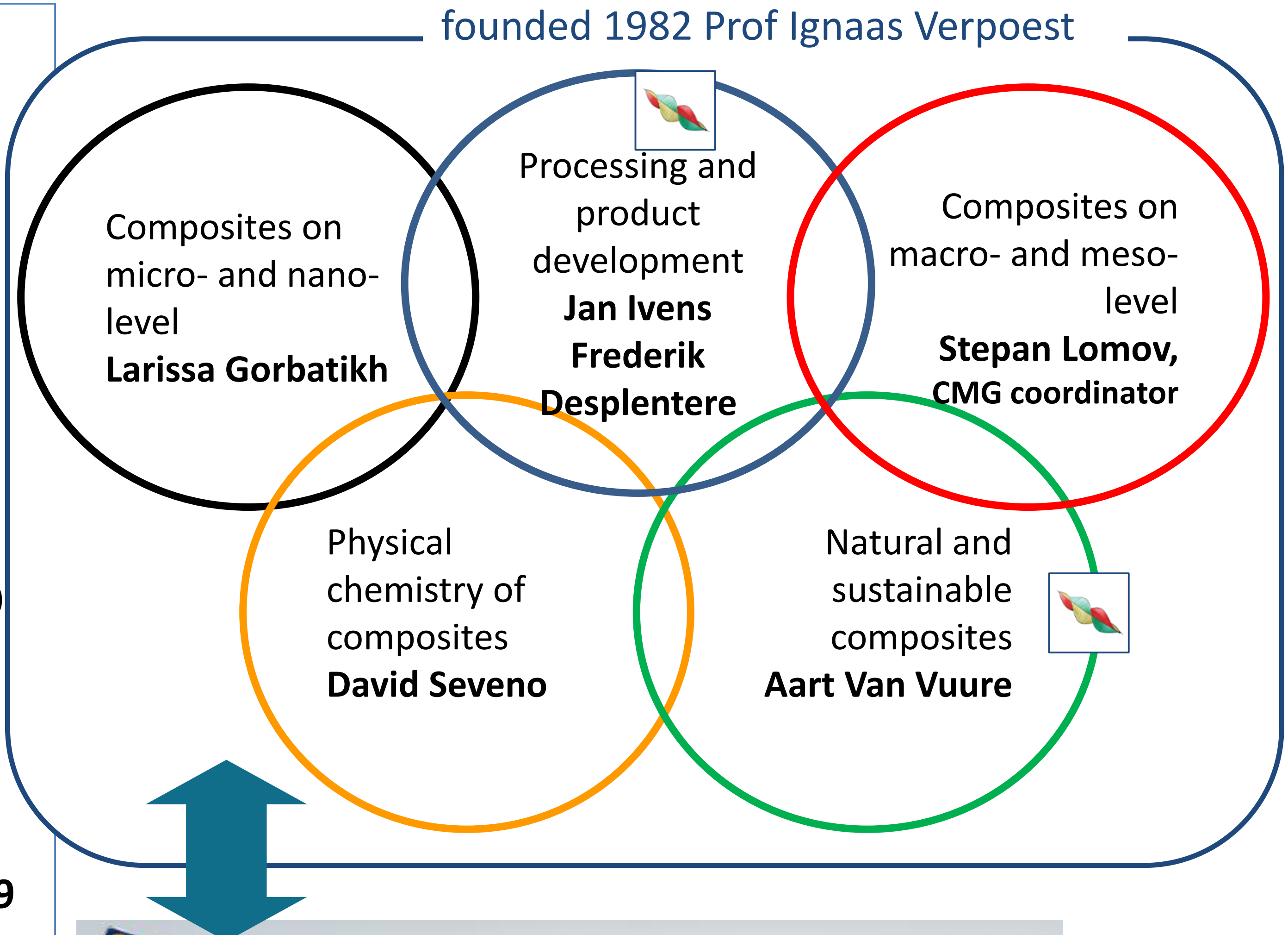
8 post-docs

24 PhD students

1-2 Visiting

2017, budget, k€

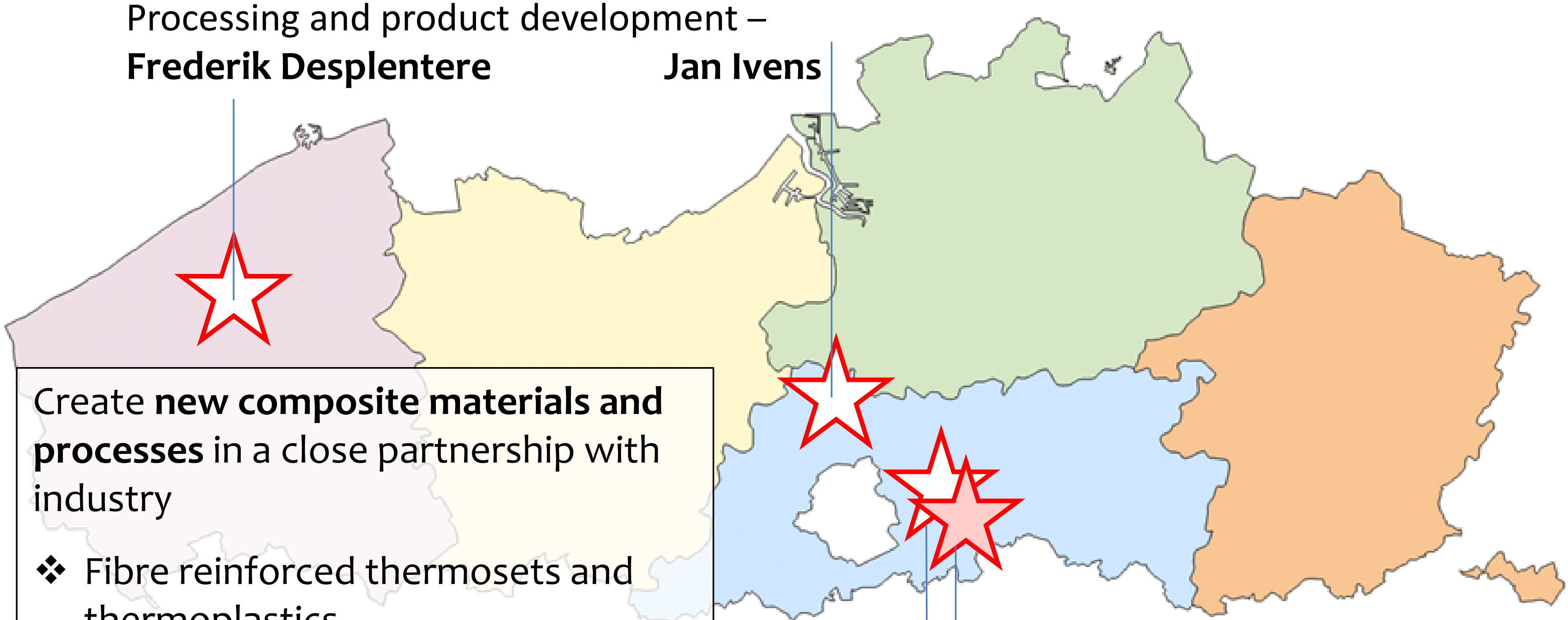
EC (FP7, H2020):	397
national:	1200
KU Leuven:	230
Industry:	236
Foreign govern.:	106
Software (est):	120
TOTAL	**2,319**



Sirris Leuven-Gent Composites Application Lab

Uniting research in four campuses

Processing and product development –
Frederik Desplentere **Jan Ivens**



Create **new composite materials and processes** in a close partnership with industry

- Fibre reinforced thermosets and thermoplastics
- Design, processing and applied physical properties (stiffness, strength, Impact, durability)
- Prediction of properties and manufacturability
- Innovative composites: hybrids, 3D printing, nano …

Physical chemistry – **David Seveno**

Micro-nano level – **Larissa Gorbatikh**

Meso-macro level – **Stepan Lomov**

Natural & sustainable composites – **Aart Van Vuure**

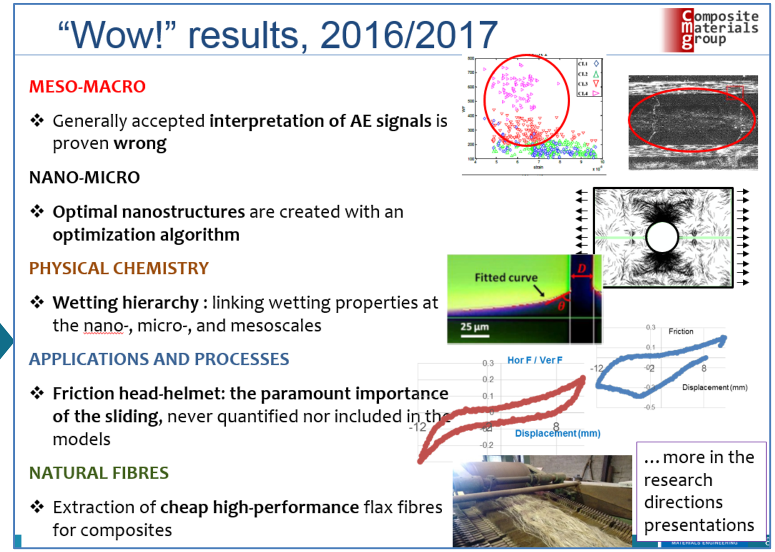
People 2017

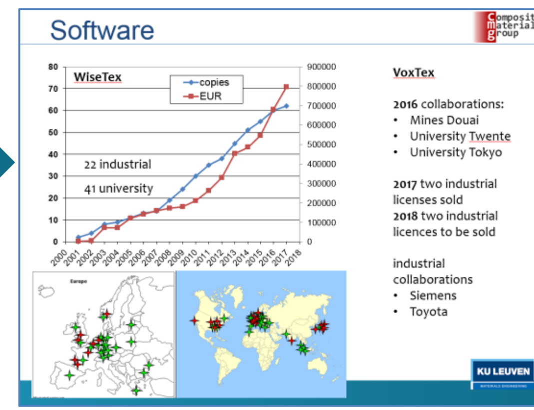
Leaders		Post-docs		PhD students					Visiting		Lab
Frederik Desplentere	Larissa Gorbatikh	Bart Buffel	Carlos Fuentes	Christian Breite	Seethal Chandramouli	Steve De Pooter	Jana De Prez	Delphine Depuydt	Akira Iwata	Tina Erdmenger	Manuël Adams
Jan Ivens	Stepan Lomov	Kirill Ilin	Quiang Liu	Ruben Geerink	Joran Geboes	Kevin Hendrickx	Gilles Koolen	Steven Latre	Dazhi Jiang	Chen Ling	Marc Peeters
David Seveno	Aart Van Vuure	Marina Selesneva	Oksana Shishkina	Morissa Lu	Fabio Malgioglio	Luca Martulli	Mahoor Mehdikhani	Arsen Melnikov	Ramon Miralbes	Nachiketa Mishra	Bart Pelgrims
Ignaas Verpoest		Yentl Swolfs	Katleen Vallons	Francisco Mesquita	Yasmine Mosleh	Nghi Nguyen	Nikolay Petrov	Rafael Santos	Fatih Oz	Paulo Reis	Kris Van de Staey
	Project engineers			Wim Six	Pedro Sousa	Ilya Straumit	Jun Tang	Nhan Vo Hong	Kristof Vanclooster	Jian Wang	
	Sofie Deceur	Cedric De Schryver	Karen Soete	Yixue Zhang	Yichuan Zhang	Yinglun Zhao	Man Zhu	Dimitrios Zouzias	Lina Osorio	Dieter Perrermans	

CMG mission

To advance composite materials science, technology and applications:

- create **new knowledge** on frontiers of science and technology and beyond
- create **new composite materials and processes** in a close partnership with industry, broadening their use and benefiting mankind
- create **new design tools,** facilitating development and implementation of new composites applications
- educate new generations of **composites scientists and engineers**
- create and maintain a world-wide research community, **"composites without borders"**





Composite Materials Group strategy

In KU Leuven	❖ **Strong interaction** between the research directions and the researchers within the composite materials group ❖ **Full integration** into the research of the department – Unified research unit ❖ Constant advancement of and investment in the **lab facilities** ❖ Collaboration with **SLC-lab** (Sirris Leuven-Gent Composites Application lab) on process and product development projects, and on knowledge dissemination
In funding	❖ **Diversification of funds** (EU, Flanders, KU Leuven, Industry, International) ❖ **Sequence**: fundamental (C1, FWO, some EU, SBO) → applied (C2/C3, EU, O&O, Industry) ❖ **Project duration** at least 2 years (industry), 3-4 years public funding. ❖ **Commercialise**, but keep open scientific exchange
In partnerships	❖ **Industrial network,** solid **university partners in Flanders**, large **EU/Japan/Russia/USA network** ❖ **Fast reaction on concrete requests** from industry ❖ **Selectivity in partners** choice (“top”), combined with “trial” collaboration ❖ **Visiting** researchers and International Scholars ❖ **Cluster** funds, create **teams**, enhance **inter-project exchange**

Toray Chair for composite materials

Composite materials group

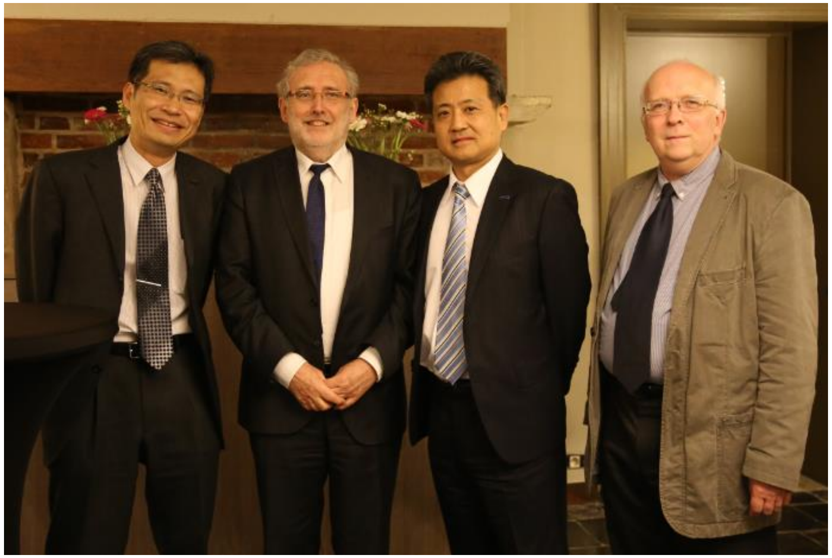
2012 - 2018

The aim of the Chair is to promote fundamental research in composite materials based on carbon fibres and other fibre types.

This fundamental research is accompanied by a suit of targeted projects of interest to Toray.

Research topics:

- introducing **new material concepts**
- knowledge-intensive optimised **manufacturing**
- **fibre and interface** advancements



Dr. Makoto Endo *(General Manager of Composite Materials Research Lab, Toray), em. Toray Professor* ***Ignaas Verpoest*** *(KU Leuven),* ***Dr. Tetsuya Tsunekawa*** *(Director, General Manager of R&D division, Toray), Toray Professor* ***Stepan Lomov*** *(KU Leuven)*

The Toray Chair enables KU Leuven to collaborate with actual and potential partners/clients of Toray.

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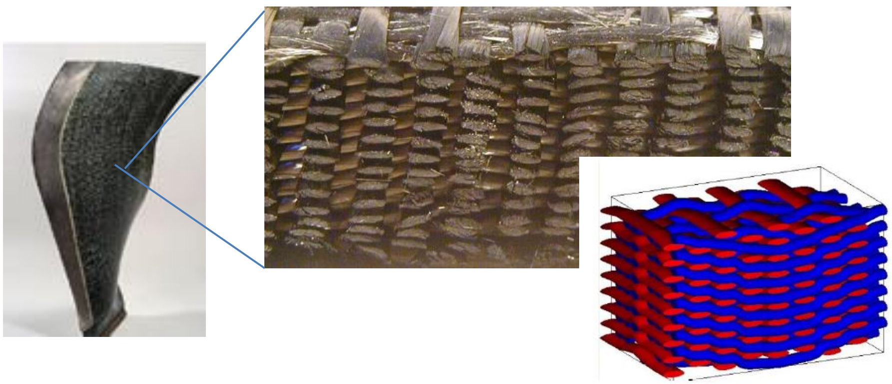
MATERIALS ENGINEERING

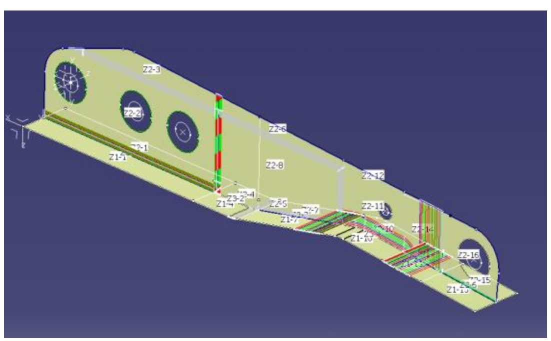
Composites applications (selected) – 1

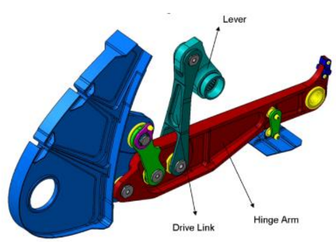
Aeronautic

Snecma 3D woven fan blade: a computational tool for optimal design



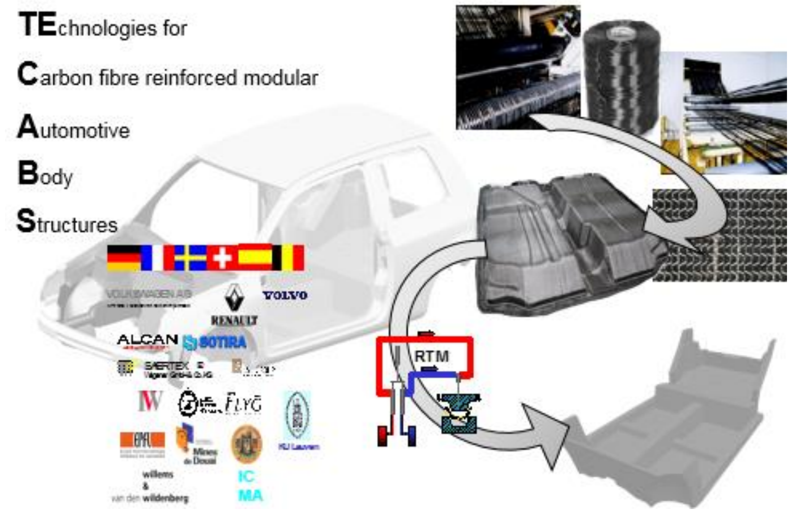
Hinge arm Airbus: ASCO





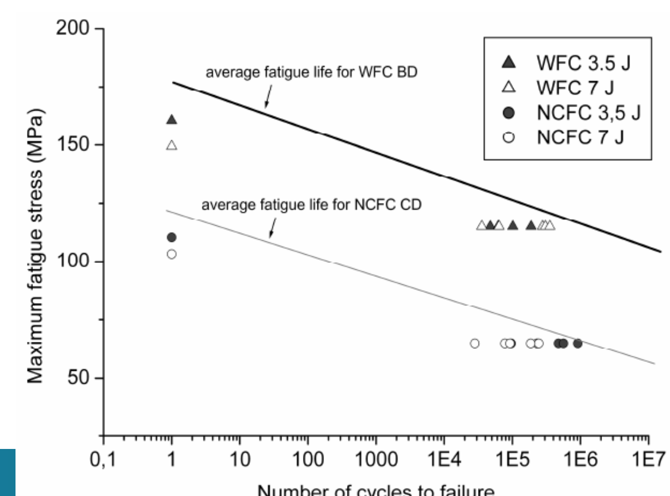
experimental validation of re-design in CFRP

Automotive



Fatigue and impact, CFRP in car body: Toyota

post-impact fatigue



Composites applications (selected) – 2

Composite Materials group

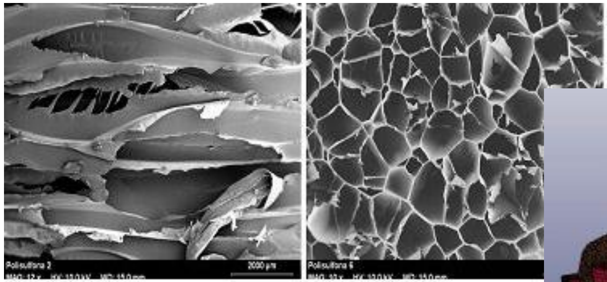
Luggage

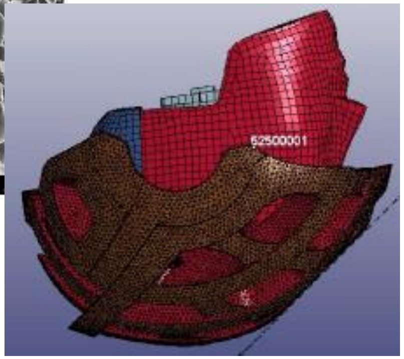
Self-reinforced composite

Samsonite **CosmoLite**

Sport

Helmets with rotation protection

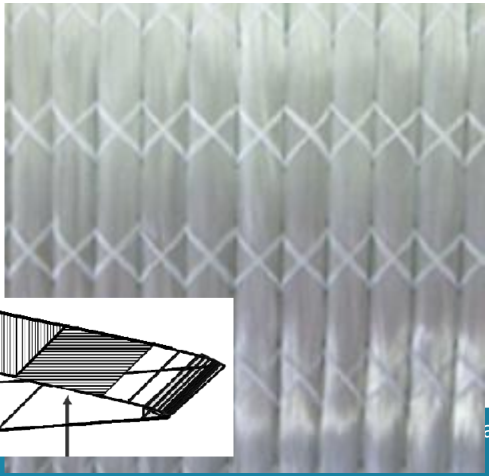


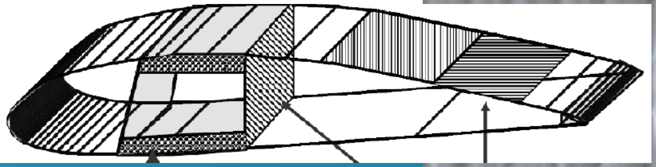


Wind energy

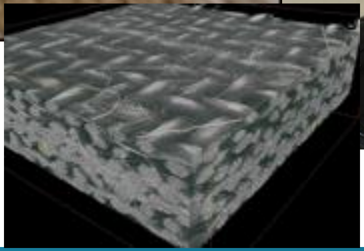
NCF optimization

Owens Corning





Bio-scooter



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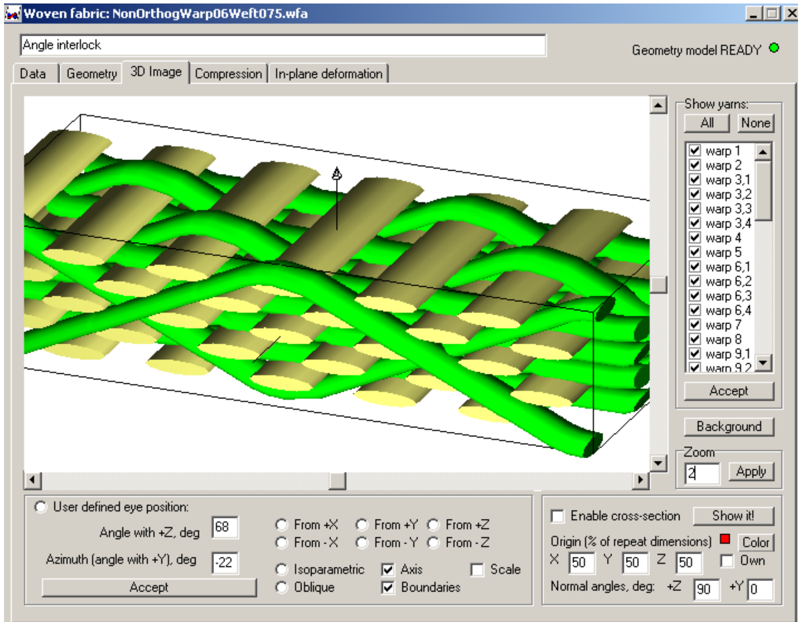
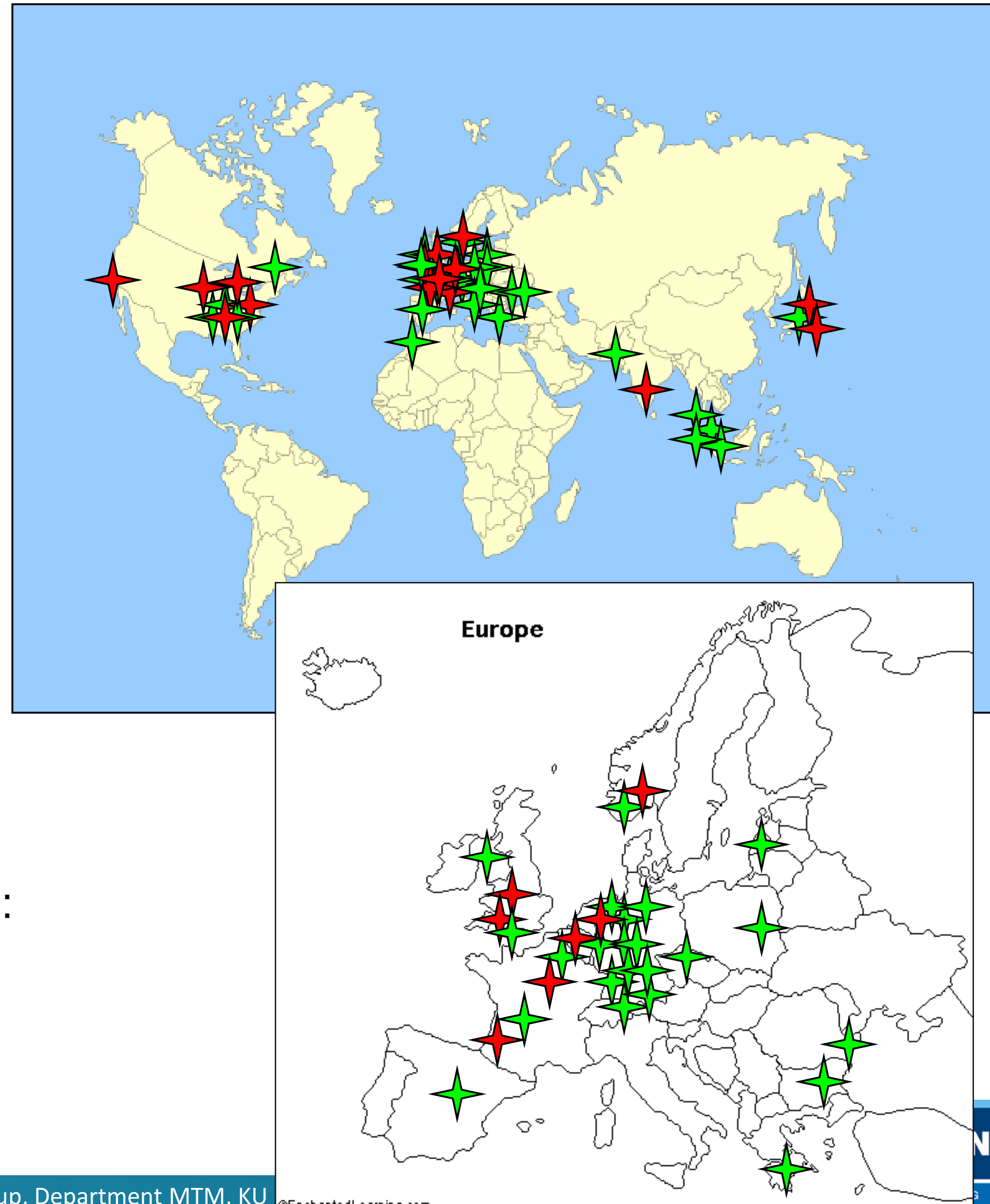
MATERIALS ENGINEERING

WiseTex: virtual textile composites





commercialised by KU Leuven – LRD

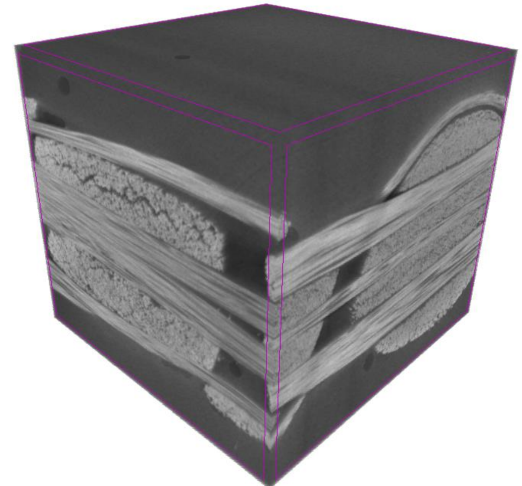
licenses, 2017:

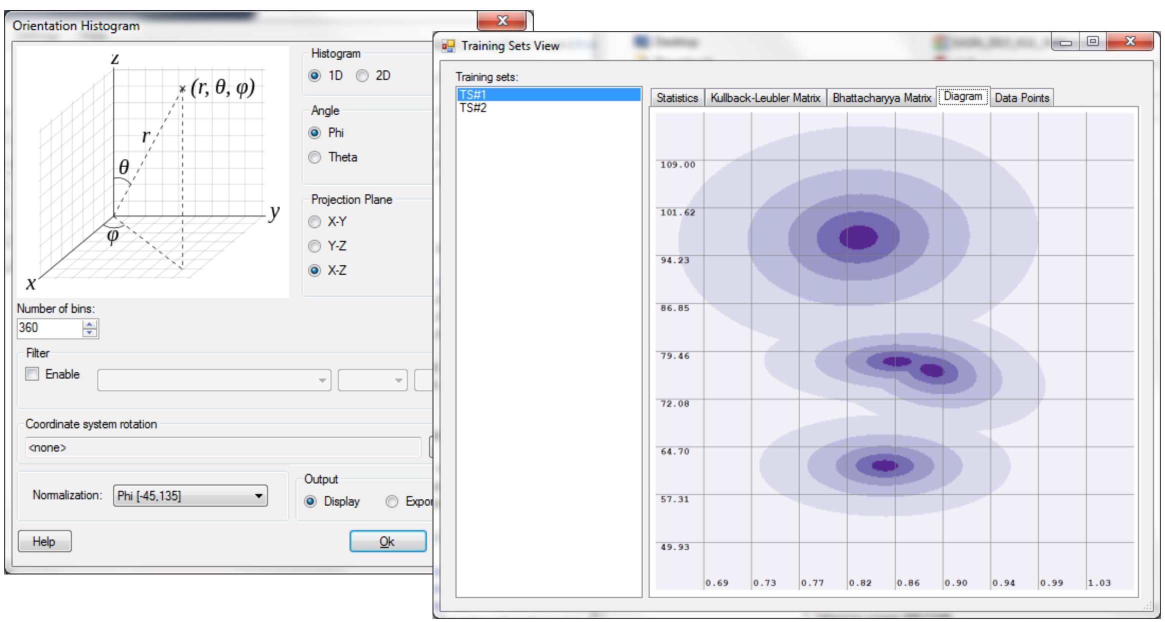
- industrial (22)
- university (40)

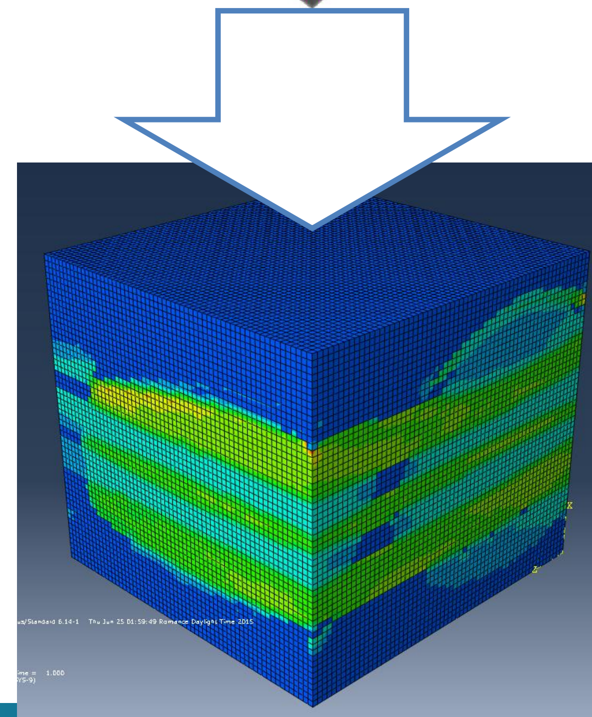
Micro-CT: Reconstruction of geometry and defects

VoxTex software, KU Leuven

- Automatic conversion of CT images into models
- Connection to ABAQUS (FEM) and FlowTex (fluid dynamics)
- Connections to ParaView and Root Data Analysis Framework for data visualisation
- Orientation analysis, misalignment analysis, image segmentation

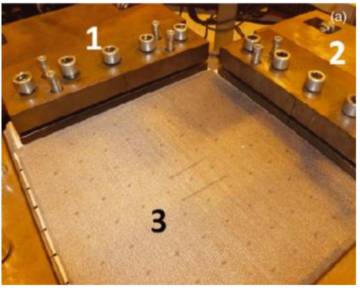


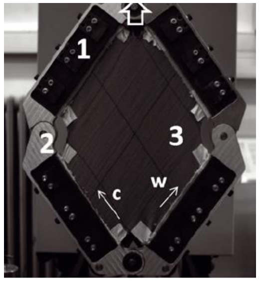


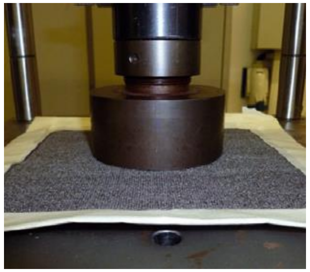


Manufacturability

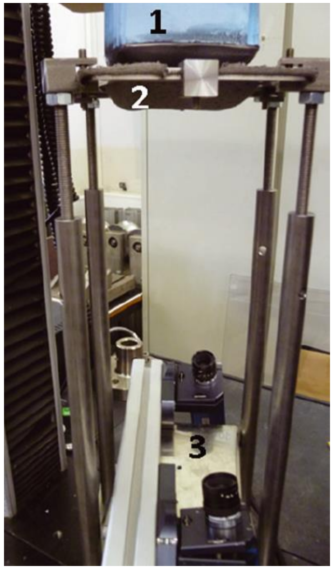
Drapability and forming

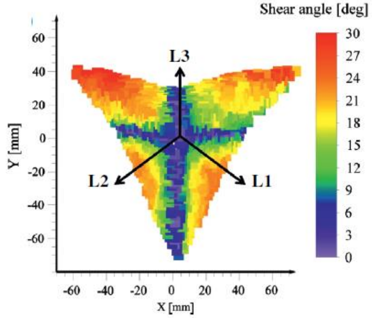






Characterisation of deformation resistance





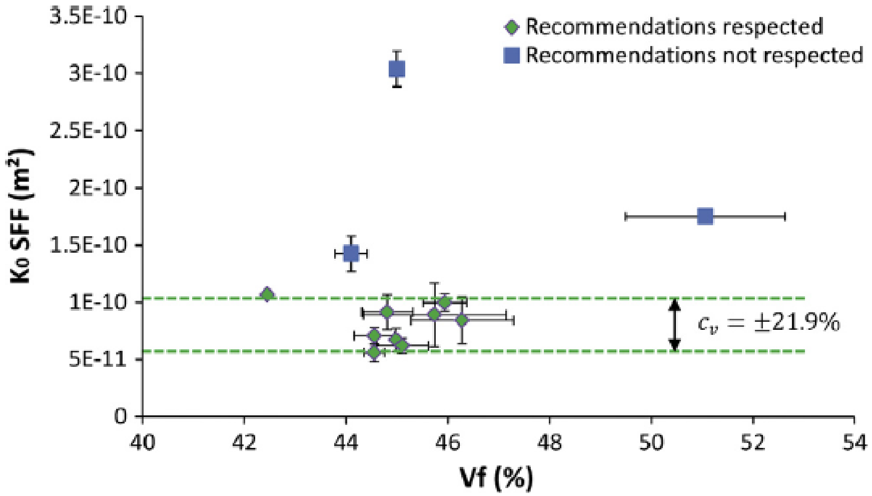
Draping measurements

Permeability

International benchmarks:

- 2D (radial) permeability
- 3D permeability
- compressibility

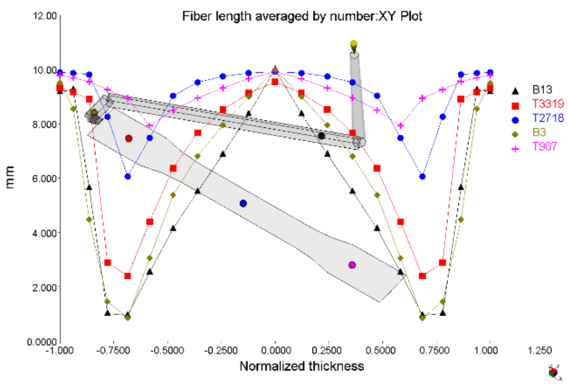
of textile reinforcements

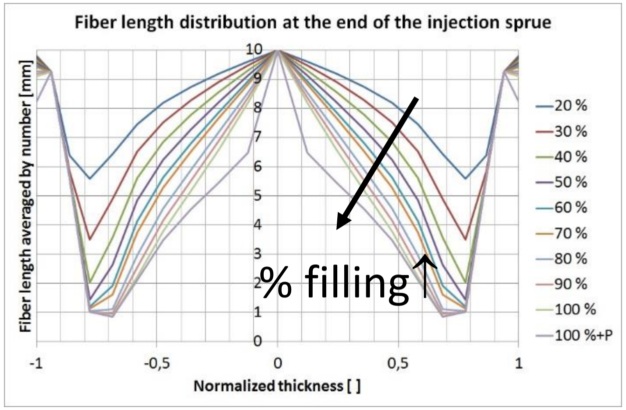


Results of the 2nd International Permeability Benchmark

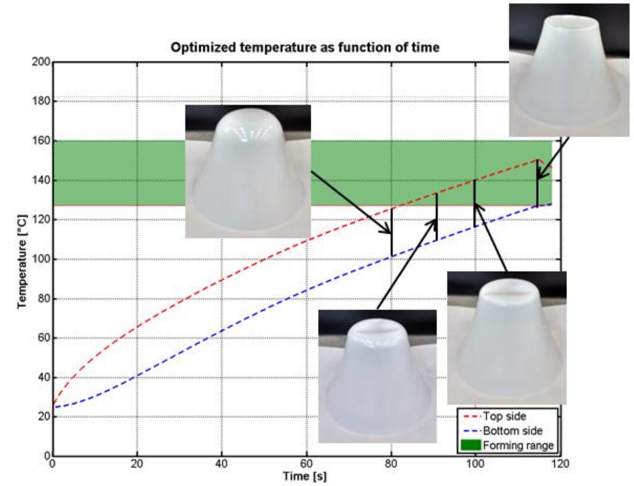
Polymer processing/performance

Fibre breakage along the screw and within the mold (Moldflow)

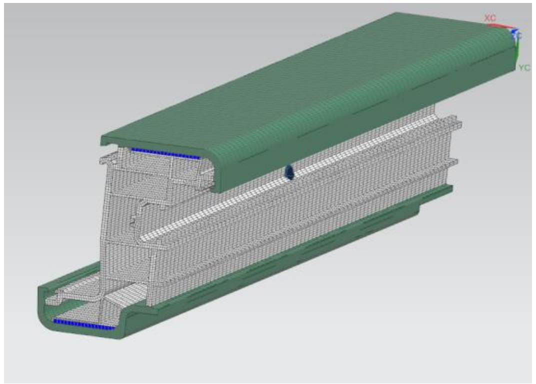


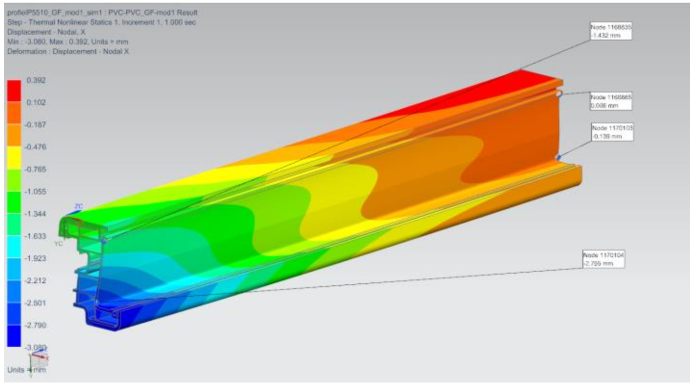


Optimized heating for thermoforming

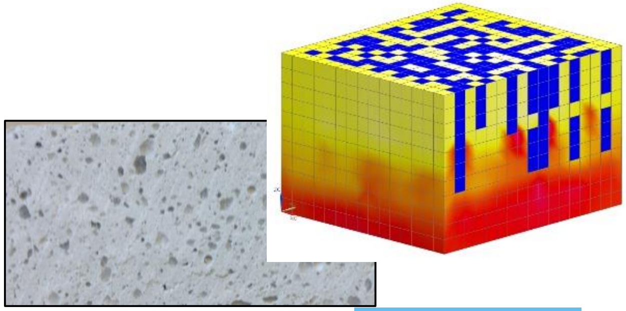


Deformation for "**composite extruded profiles**"





Thermal performance of multiscale structure



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MATERIALS ENGINEERING

Thermoplastic composites

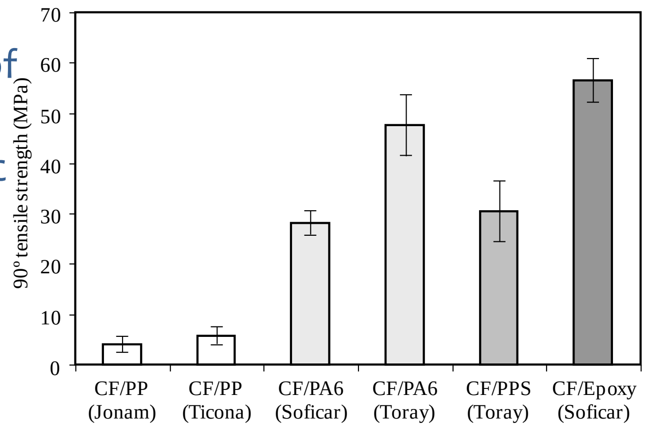
Composite Materials group

Composites with thermoplastic matrices

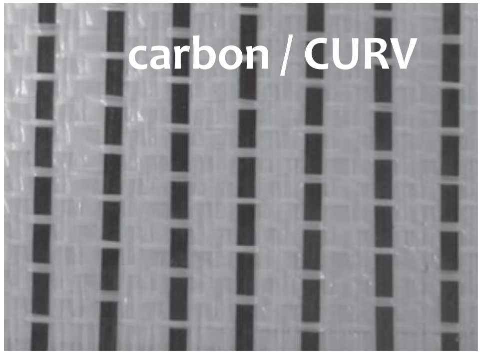
PP, PA, PPS, PEEK, PET, …

+ multi-phase matrices

comparison of CF thermoplastic tapes



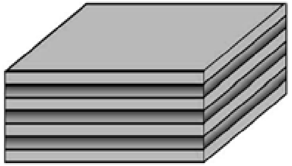
Fiber hybridisation



Material development with different hybridization concepts

Designing for ductility, impact performance, translaminar toughness

Understanding hybrid effects through modelling

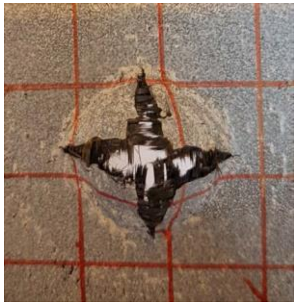


High performance polymer fibres and their composites

PBO

PAR

Aramid

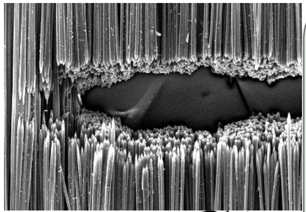


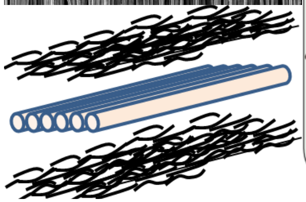
Impact, translamminar toughness, compressive properties …

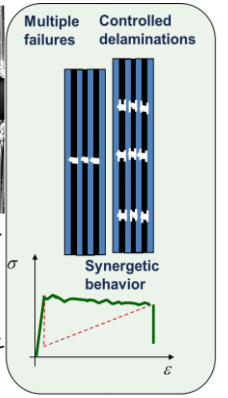
Discontinuous fibre composites

Developing concepts for pseudo-ductile behavior

Micro-structural design for tailored performance



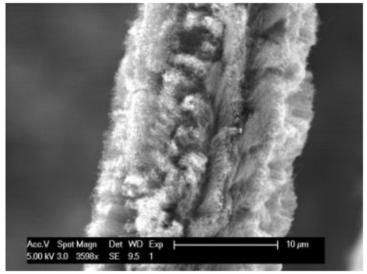




Toughening of composites

Composite Materials group

Nano-engineered composites

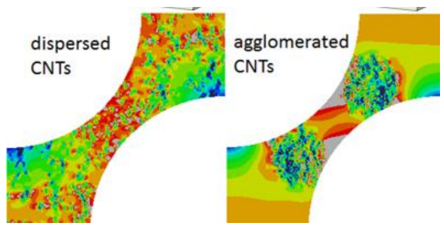


Understanding toughening mechanisms

Composite processing

Nano-structure control and optimization

Nanotube localization



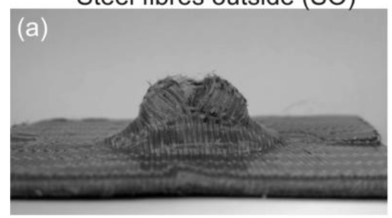
Composites with ductile fibres

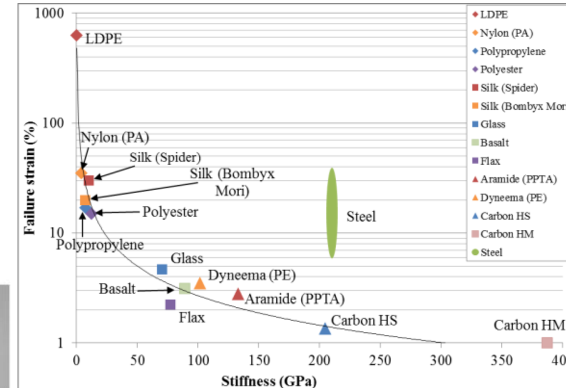
Ductile steel fibers

Polymer fibers

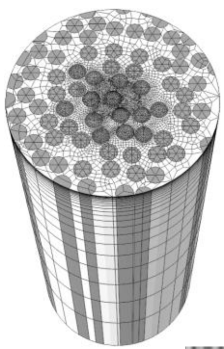
Ductility and impact performance

Steel fibres outside (SO)





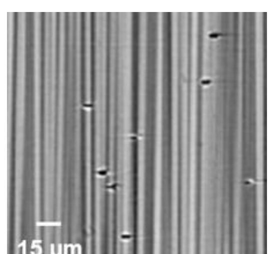
Model development



Predicting composite strength using in-house developed fiber break models

Validation using Synchrotron CT data from in-situ experiments

Models for nano-engineered composites

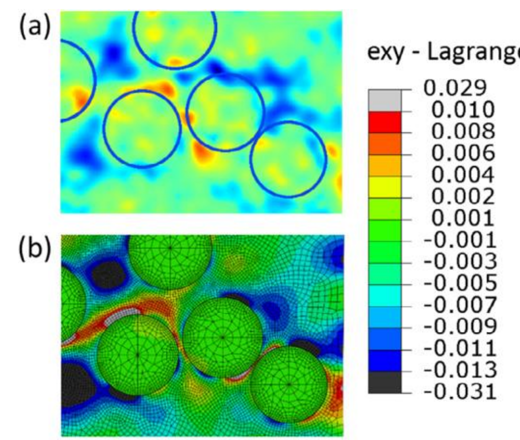


Advanced characterization at different scales

In-situ characterization of failure processes

Dedicated experimentation at different scales

Link to modelling predictions



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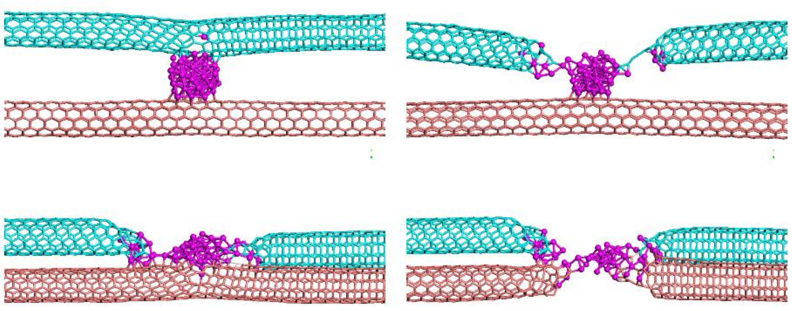
MATERIALS ENGINEERING

Nanoscale simulations

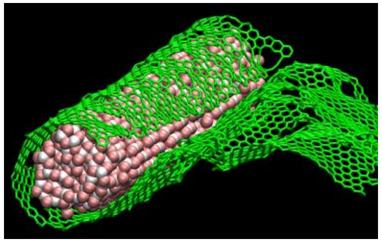
Carbon Nanotubes

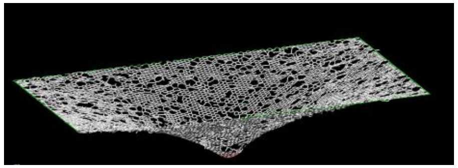


- Reactive molecular dynamics
- Effect of defects
- Failure of Carbon Nanotubes

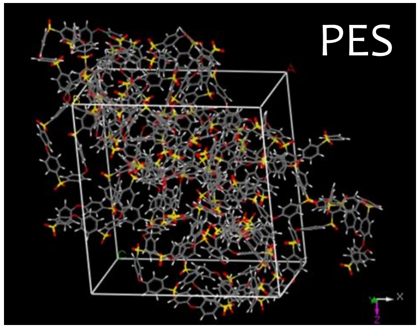
Graphene

- Graphene (Defect free) & Reduced Oxide Graphene
- Interactions with nanoparticles
- Application: batteries



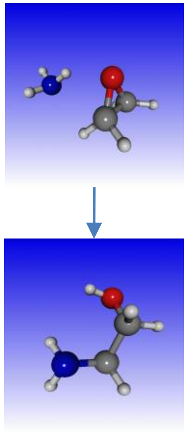


Thermoplastics



- Mechanical properties
- Thermal properties
- Structural properties
- Diffusion
- Solubility

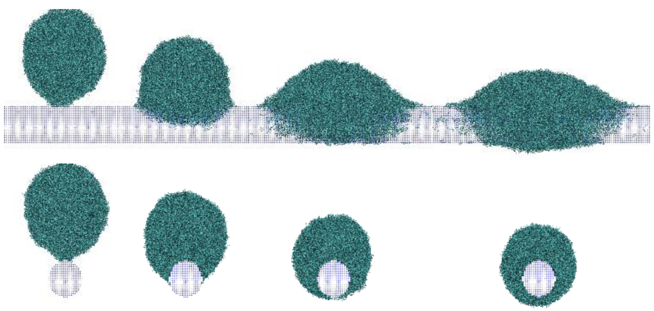
Thermosets



- Reactive molecular dynamics
- Crosslinking process
- Network structure
- Effect of fiber surfaces on the network structure
- Mechanical properties

Impregnation of fibers

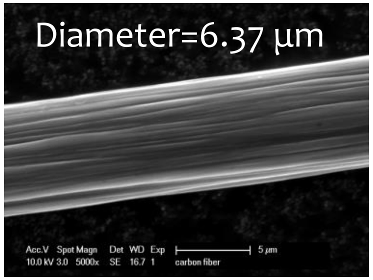
Nanoscale



- Molecular dynamics simulations
- Spreading dynamics
- Mechanisms, Adhesion

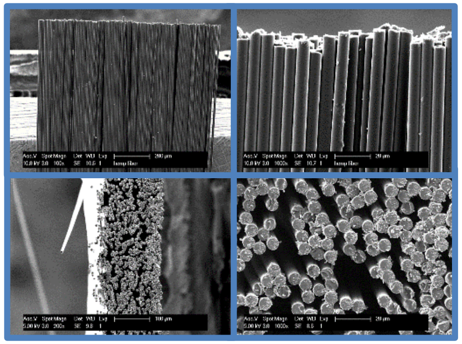
Microscale

- Single fiber scale
- Unique methodology
- Carbon, glass, polymer fibers
- Capillary forces & contact angles
- Effect of roughness
- Effect of surface chemistry

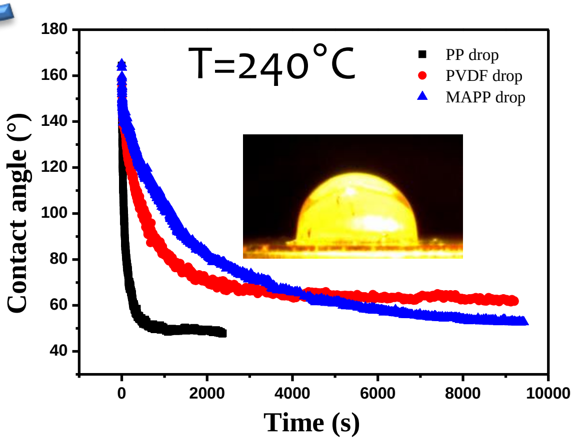


Mesoscale

- Tow scale
- Advanced set-up
- Carbon fibers
- Effect of sizing
- Link with the microscale



Macroscale

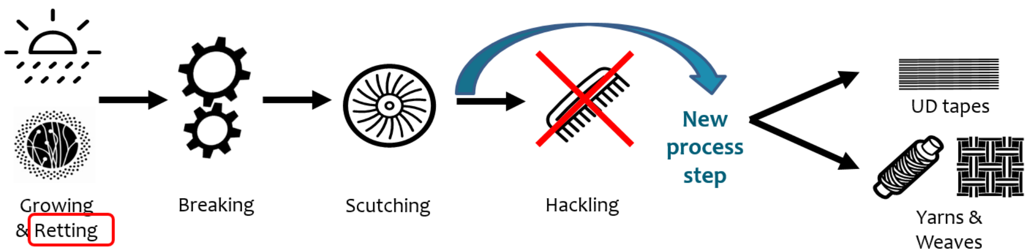


- Molten thermoplastics
- Glass slide
- Surface tension, viscosity, adhesion
- Reactive wetting

Natural and sustainable composites (1)

Improved extraction and processing methods for natural fibres

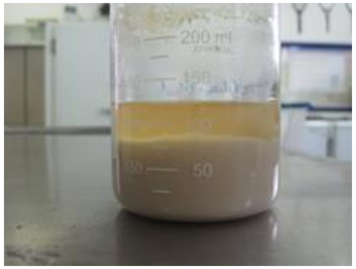
- Mechanical extraction of bamboo fibres
- Development of bamboo fibre tape
- Preforms based on scutched-only flax fibres
- Enzymatic extraction

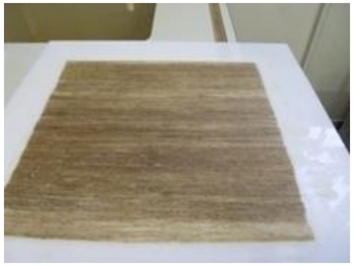


Bamboo fibre tape

Development of bio-based matrices

- Gluten bio-polymers
- Bio-based epoxies and hardeners
- Gluten prepreg by suspension-solution impregnation



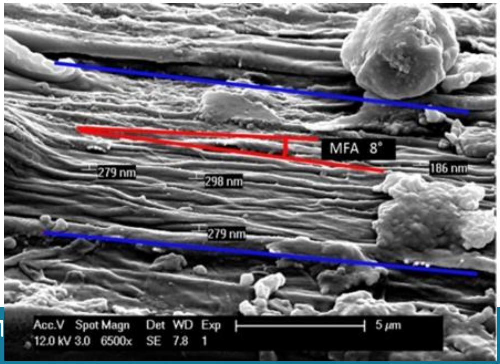


Recycling of composites

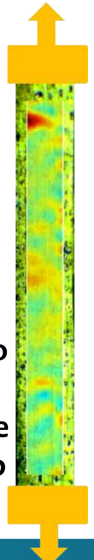
- Re-use of GFRP as rebars in geopolymers
- Recycling of GFRP in geopolymers

Characterisation of natural fibres

- Single fibre testing
- Micro-DIC, micro-CT
- Impregnated Fibre Bundle Test (CELC)



Micro fibrillar angle

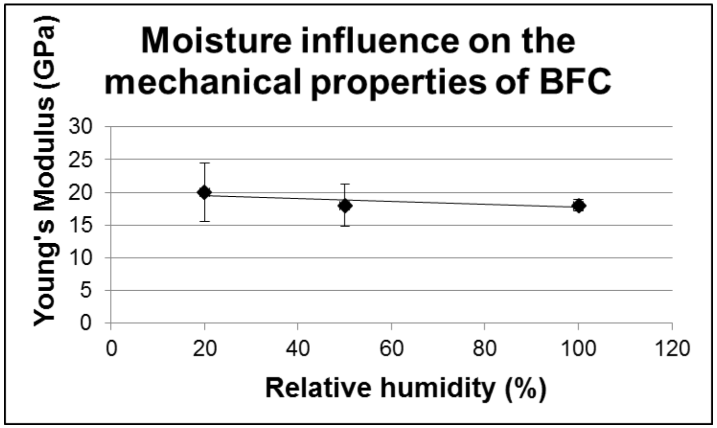


Micro DIC single hemp fibre

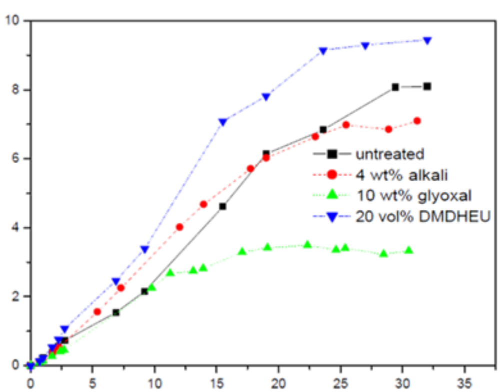
Natural and sustainable composites (2)

Durability of (natural fibre) composites

- Hygrothermal ageing
- Improving the fibre-matrix interface
- Lowering the EMC of natural fibres
- Processing natural fibres without drying
- Selecting natural fibres with low moisture sensitivity



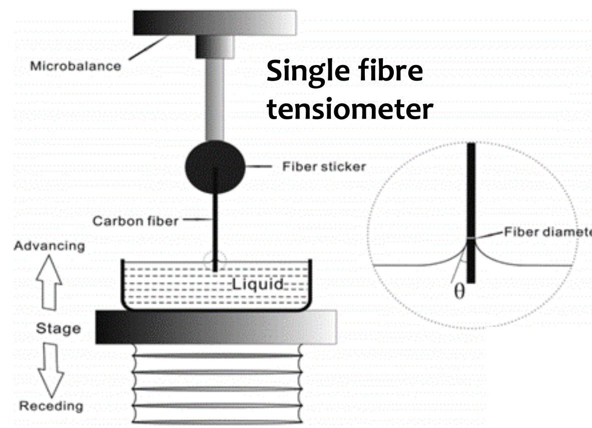
Bamboo fibre composite: limited reduction in modulus



Chemical treatment to lower EMC; % moisture uptake of flax-epoxy after 30 days at 90% RH

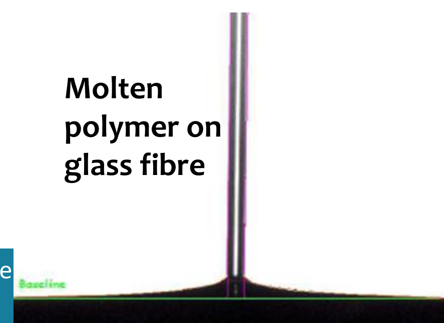
Modification of fibre-matrix interface

- **Integrated physical-chemical-micromechanical approach**
- Chemical surface characterization
- Contact angle measurements to determine surface energy components
- Micro-mechanical testing of adhesion
- Fibre treatment or matrix modification
- Natural and other fibres (glass, aramid, Carbon)
- Characterisation of molten thermoplastics

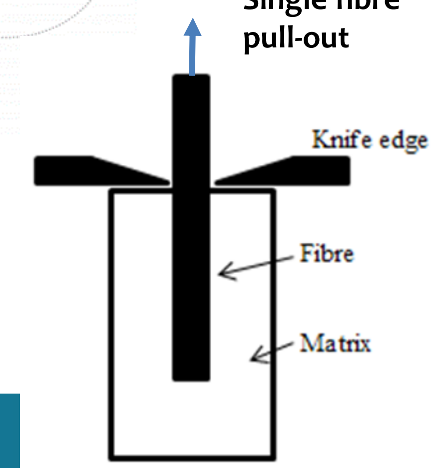


Single fibre tensiometer

Molten polymer on glass fibre



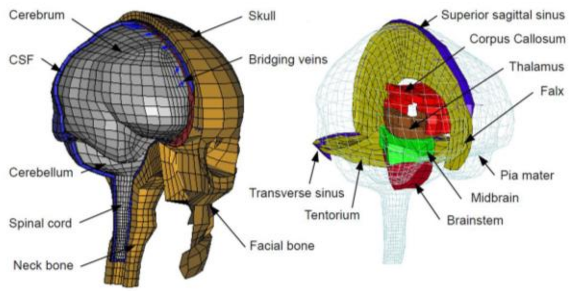
Single fibre pull-out



Improved protection for head impact

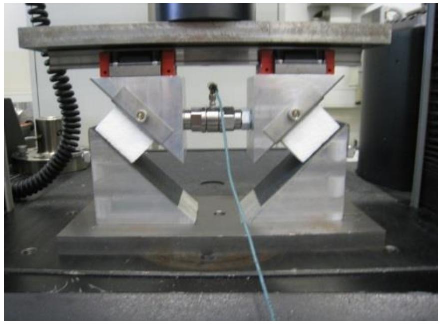
Understanding effects of oblique impact
(inducing severe rotation)

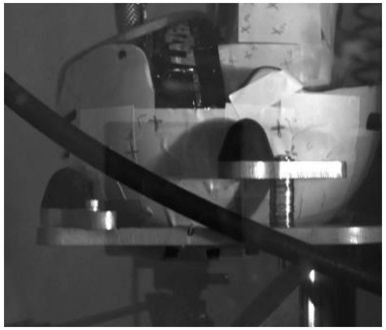
- Biomechanical studies
- Accident reconstruction
- Analysis on bridging vein rupture, contusions, …



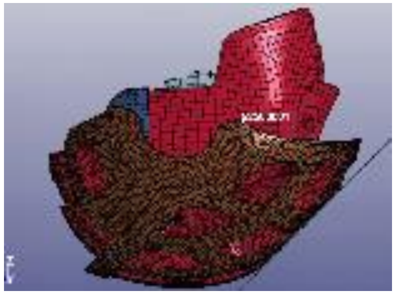
Development of test methods

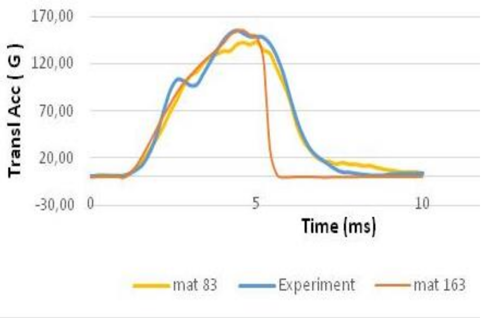
- Low to high strain rates
- Material and helmet testing





Simulation for virtual helmet design
(inducing severe rotation)





- Validation of FE model using experiments
- Optimisation of topology and helmet composition

Innovative material concepts for improved protection

- Anisotropic liners improve protection
- Patented concepts