sccer mobility

Swiss Competence Center for Energy Research
Efficient Technologies and Systems for Mobility

In Zusammenarbeit mit der KTI

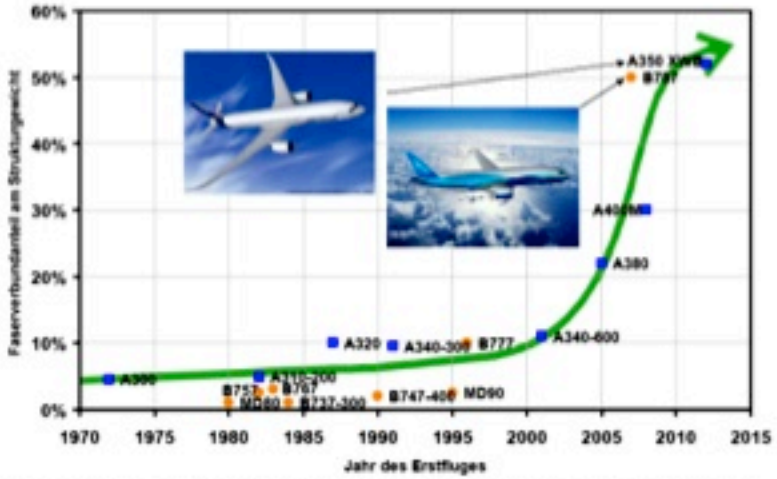
Energie
Swiss Competence Centers for Energy Research

A3. Minimization of vehicular energy demand

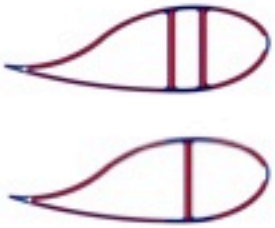
Presenter: Prof. André R. Studart, ETH Zürich

1st Annual Conference SCCER Mobility, 11th September 2014, ETH Zürich

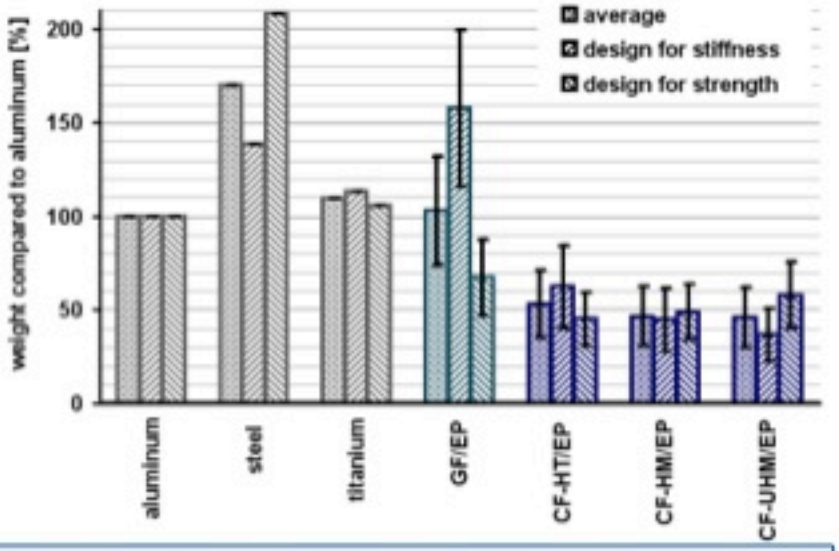
High performance composite have proven their performance and reliability in different industry sectors, including…



L. Herbeck, H. Voggenreiter, DLR Center of Excellence Composite Structures; Werkstoffsymposium Fahrzeugtechnik, Stuttgart, 3. & 4. Juli 2007



Megacity-Vehicle www.bmw-i.de



Fiber reinforced polymer structures have an exceptional lightweight performance due to the **outstanding specific stiffness and strength** of the material and the **superior fatigue behavior**.

But …

Long processing times & high costs

Brittle & susceptible to impact damage

Mostly structural parts / unexploited functionalities

Our goal

Identify new composite technologies to improve performance and reduce costs for mobile applications

Our team

Dr. Gil Georges
Aerothermochemistry
& Combustion Systems Laboratory
ETH Zürich (Prof. Boulouchos)

Prof. Clemens Dransfeld
Institute for Polymer Technology
FHNW

Mr. Stève Mérillat
CC Schweiz

Prof. Paolo Ermanni
Composite Materials
& Adaptive Structures
ETH Zürich

Prof. Véronique Michaud
Laboratory of Composite
& Polymer Technology
EPFL

Dr. Christian Fischer
BComp

Prof. André Studart
Laboratory for Complex Materials
ETH Zürich

How to improve manufacturing to reduce costs ?

Prof. Clemens Dransfeld
Institute for Polymer Technology
FHNW

Prof. Paolo Ermanni
Composite Materials
& Adaptive Structures
ETH Zürich

Prof. Véronique Michaud
Laboratory of Composite
& Polymer Technology
EPFL

Long processing times & high costs

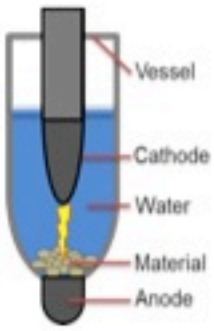
Prof. Clemens Dransfeld
Institute for Polymer Technology
FHNW

Ms. Julia Studer

Institute of Polymer Technology (IKT)
University of Applied Science and Arts Northwestern Switzerland (FHNW)

- **Head: Prof. Clemens Dransfeld, International team of ca. 30 scientists and engineers**
- **Processing of thermoset and thermoplastic composites**
- **Thermoset composites: fast processing via compression RTM and fast curing resin**
- **Thermoplastic composites:**
  - Complex parts from discontinuous fibre composites
  - Recycling by electrodynamic fragmentation

  - Natural fibre composites
  - Pultrusion of CF-PEEK



M. Roux et al ICCM 19, 2013: Montreal

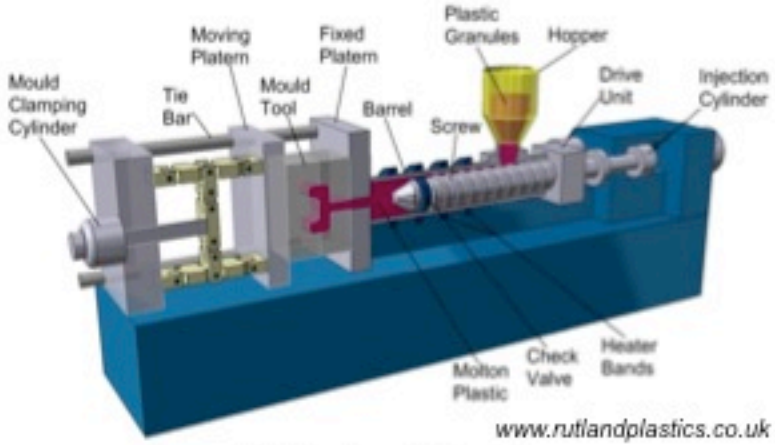
THERMOPLASTIC FABRIC REINFORCED COMPOSITES MADE BY **INJECTION MOULDING**

- **Motivation of the work: Composites with high fibre volume content**

- **Why Composites:**
  - Lightweight design, reduction of energy demand (BMWi3)
  - Fast processing, reduction of manufacturing cost: Automotive
  - Thermoplastic matrix for recycling

www.bmw.com/www.autoevolution.com

- **Why using an injection moulding machine?**
  - Short cycle time
  - Repeatable process
  - Technology widely used in industry

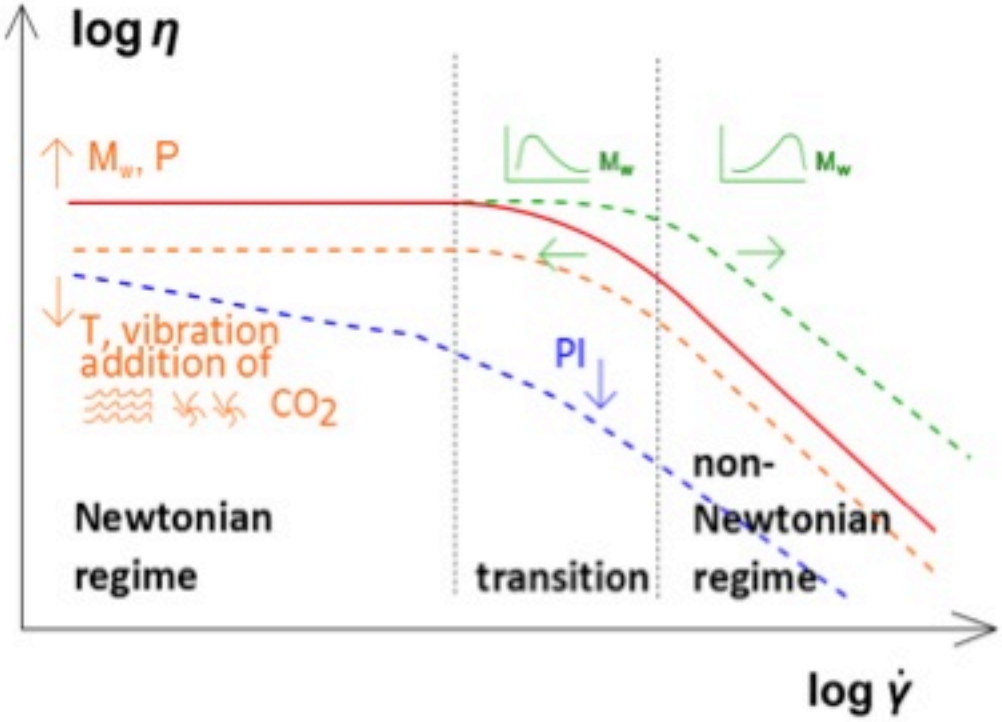


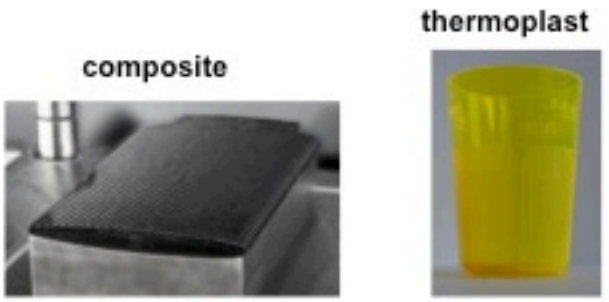
www.rutlandplastics.co.uk

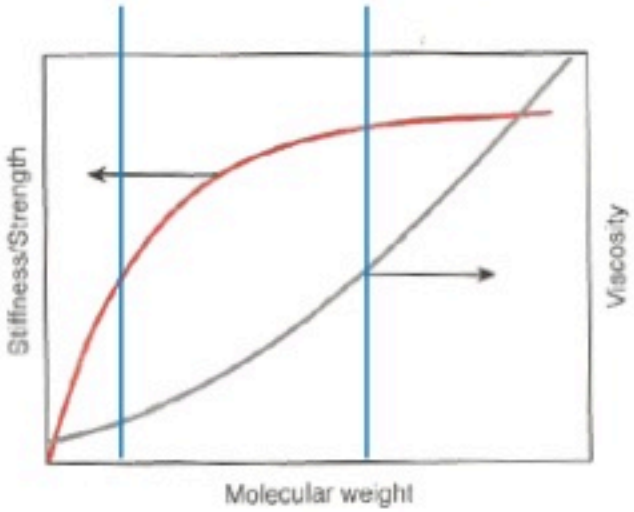
  - **Problem:** high viscosity of the matrix makes impregnation of fabrics difficult

Viscosity reduction of the thermoplastic matrix

- Further investigation of known principles used for polymer parts with regard to matrix materials in composites
- Different requirements on mechanical properties





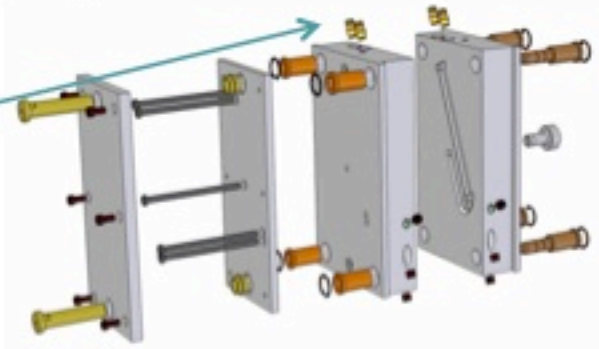


Materials Science of Polymers for Engineers, Menges/Osswald, Hanser (2012)

Adaptation of the injection moulding process for fabric impregnation with low viscous thermoplast

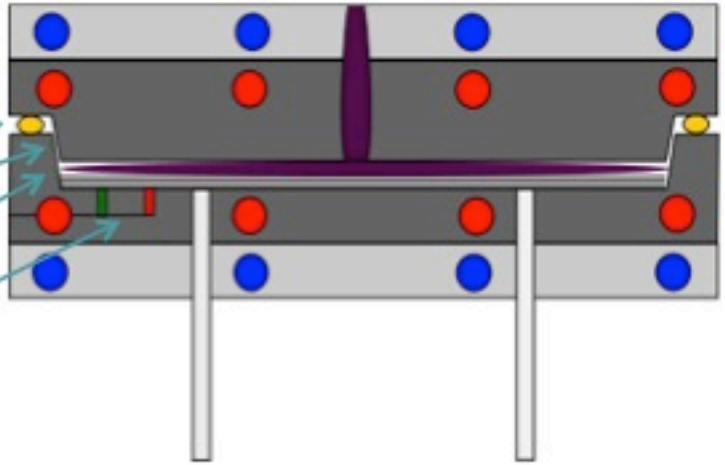
Classical injection moulding

- Horizontal machine
- isothermal mould
- no vertical shut-off
- no embossing stroke
- no sealing
- no vibration



Topics to be addressed in the adapted process

- Vertical machine
- Shut-off nozzle
- Variothermal mould
- Sealing
- Vertical shut-off
- Embossing stroke
- Temperature and pressure sensors
- Vibration
- …



Prof. Paolo Ermanni
Composite Materials
& Adaptive Structures
ETH Zürich

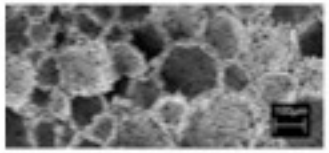
Dr. Joanna Wong

Competences span from material science to novel engineering applications

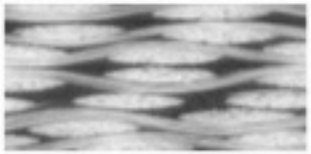
Material portfolio

Adaptive materials

Structured materials

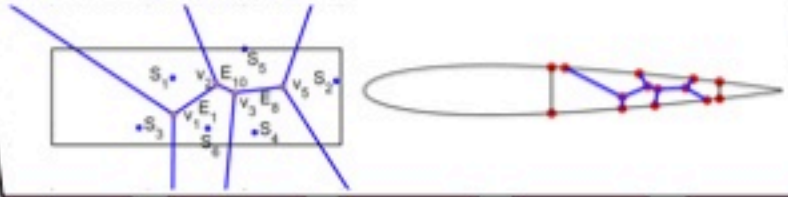


Cellular materials



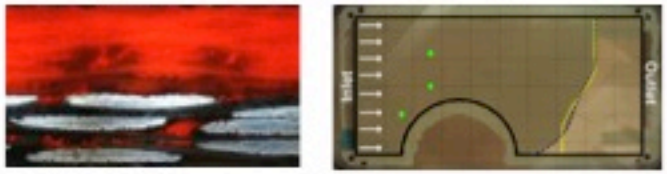
Polymer Composites

Development of models and more efficient numerical methods.



Design, fabrication and characterization of intelligent material systems

Understanding/control of complex impregnation & curing phenomena



Engineering applications

- Smart handling of vibrations
- Tunable stiffness elements
- Aeroelastic morphing
- Tailored design solutions
- Intelligent fabrication processes

Innovative products with increased customer value

Focus within SCCER

- **Novel yarn technologies** possess the potential to fill the existing gap along the value chain, between the constituent materials and the manufacturing step.
- We will focus on the direct consolidation of fiber reinforced **thermoplastic composites** based on novel approaches on hybridization and commingling.

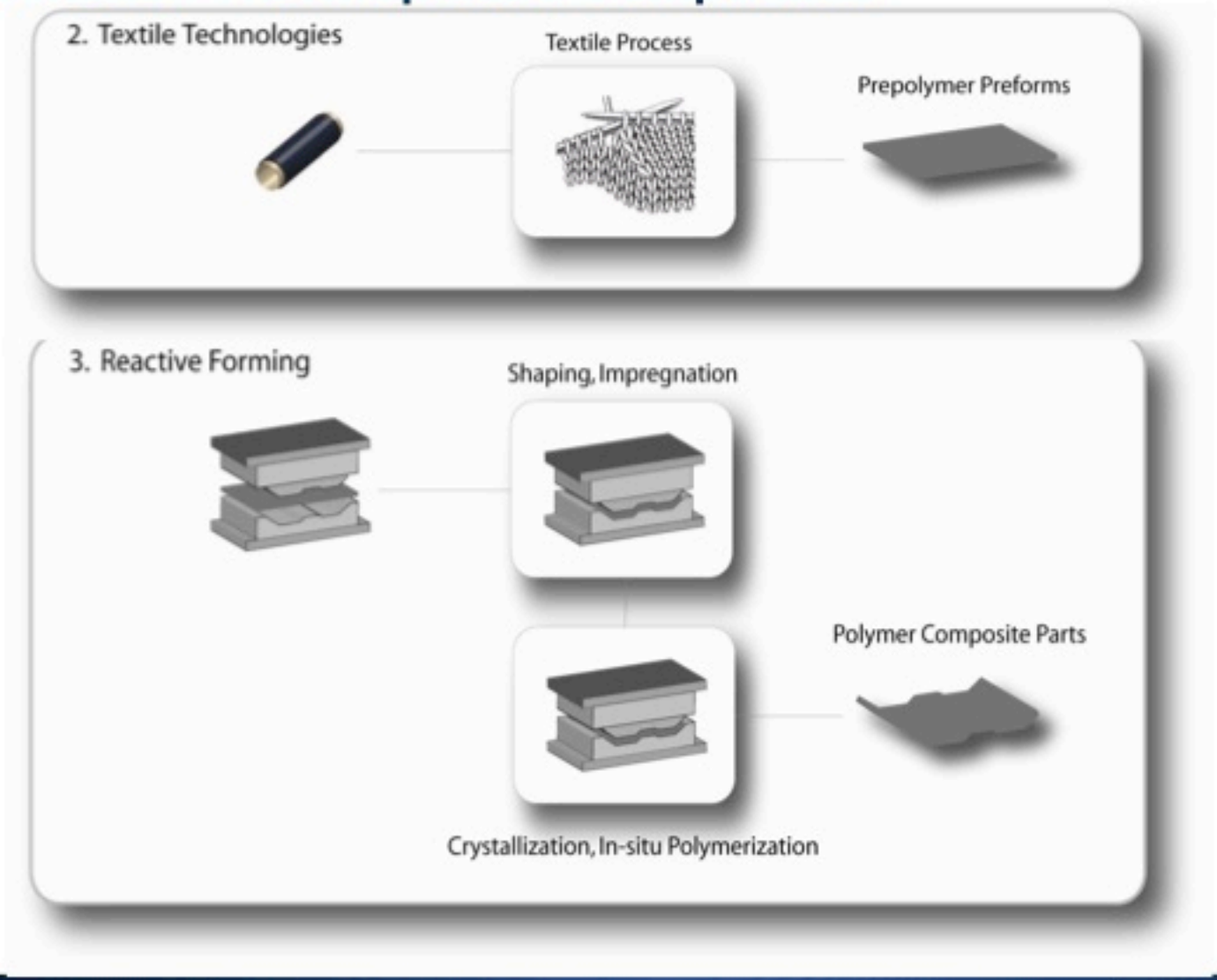
Oligomere Technologies for Cost-Effective Processing of High-Performance Thermoplastic Composites

- Low cost processing route for PPA - composites
  - Exploit the low viscosity of Prepolymers for impregnation of prepolymer prepregs
  - Conduct the polymerization in the textile reinforcement
- Idea: Bridge the gap of «low cost polymer to high performance composites» by using Polyphtalamide (PPA)

PA 6T/6I Prepolymers

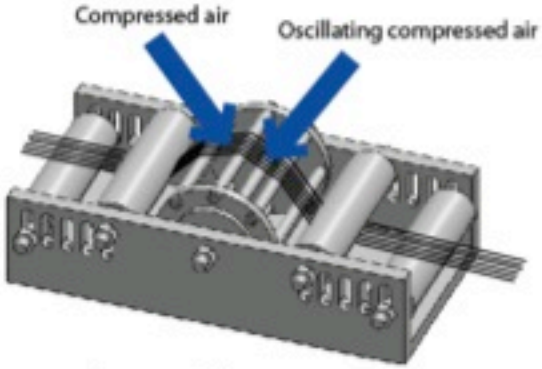
Pini M, Zaniboni C, Busato S, Ermanni P, Perspectives for reactive molding of PPA as matrix for high-performance composite materials, Journal of Thermoplastic Composite Materials, 19 (2): 207-216, 2006

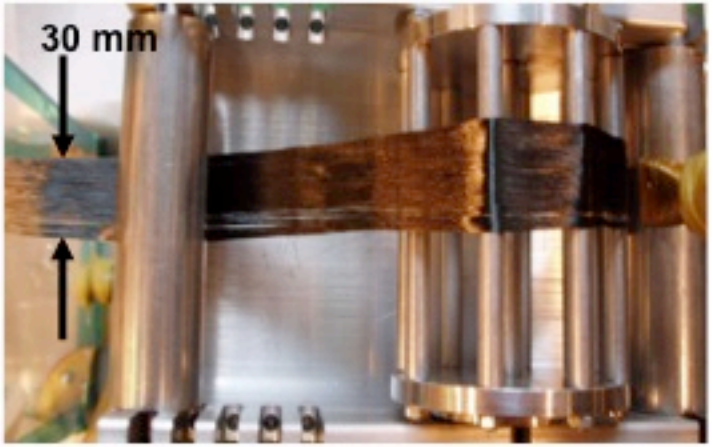
Oligomere Technologies for Cost-Effective Processing of High-Performance Thermoplastic Composites

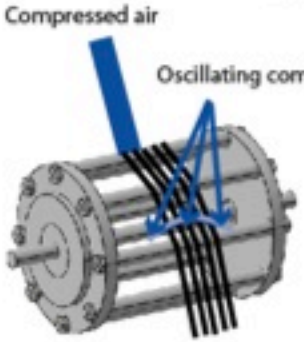


Oligomere Technologies for Cost-Effective Processing of High-Performance Thermoplastic Composites

- Development of a dry powder impregnation unit
  - Spreading mechanisms for fiber tows
  - Bonding of dry powder to fiber tows by electrostatic forces







Prof. Véronique Michaud
Laboratory of Composite
& Polymer Technology
EPFL

Dr. Sara Dalle Vacche

Mr. Maxime Cattin

Mr. Damiano Salvatori

Laboratory of Composite and Polymer Technology (LTC-EPFL)

Created: 1990
By Prof. Jan-Anders E. Månson

Affiliation
- School of Engineering @EPFL
- Material Science and engineering

Director:
Prof. Jan-Anders E. Månson
Direction:
P-E Bourban, Y. Leterrier, V. Michaud,
C. Plummer, K.Schadegg
Secretariat:
C. Chariatte, M. Klincewicz
Staff :
12 post-doctoral researchers
16 doctoral students
8 engineers
2 visiting scientists

Research domains
- Cost effective manufacturing
- Implementation strategies
- High performance composites
- Smart composites
- Multi layer thin films
- Nano composites
- Bio composites

Main industrial partners
- OEM's: Aerospace, Automotive, Packaging, Sport equipm.
- Johnson Controls, Vetrotex, ABB, Bekaert, KB
- Quadrant, DuPont, Dow, EMS Chemie, Firmenich, Solvay
- Philips, Tetra Pak, Alinghi, Solar Impulse

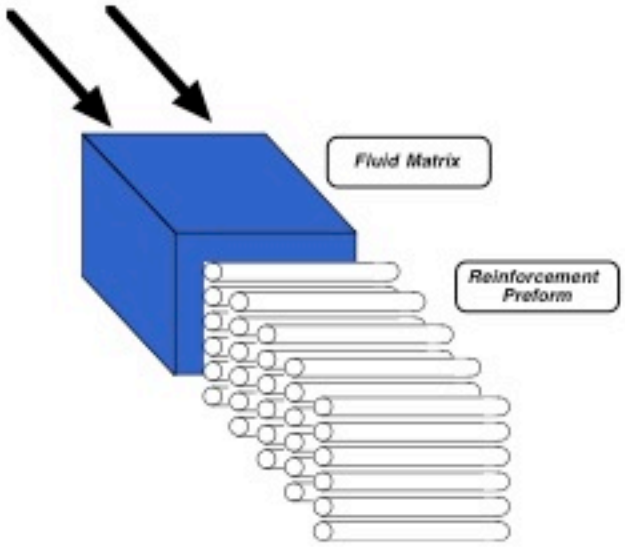
Research core competences

Area of activities in the SCCER

- Develop robust **Liquid Composite Moulding (LCM) processes** with **thermoplastic matrices**, suitable for transport applications, ie with suitable structural properties, for high production volumes (i.e. short production cycle time, low cost), possibly suitable thermal insulation properties.
- Perform technical studies, as well as **Technical Cost and Life Cycle Assessment** for thermoplastic composite processes in mobility applications

What is Liquid Composite Moulding (LCM) ?

LCM belongs to infiltration processes, whereby the liquid matrix flows into a dry porous medium over a distance that is greater than the length-scale of the reinforcement (a fiber bundle, a few fiber bundles)



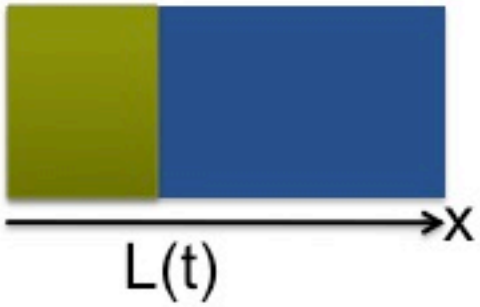
Infiltration

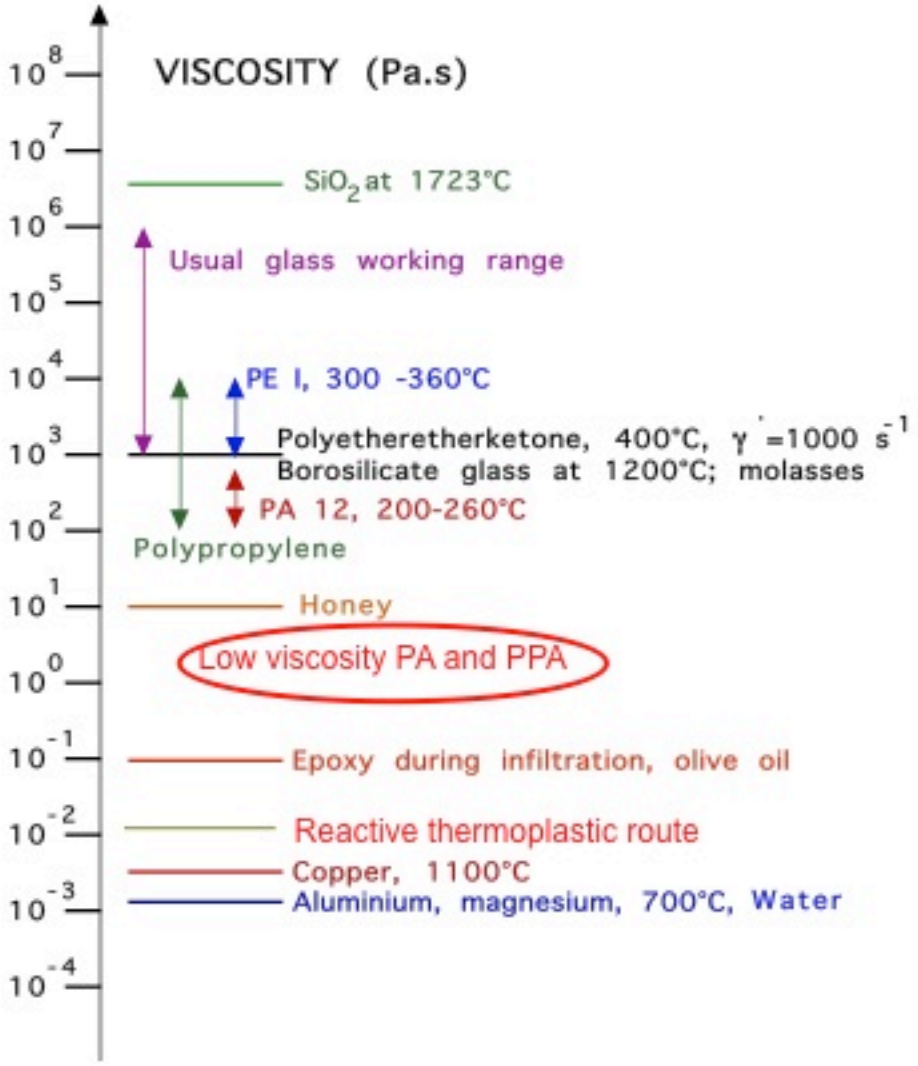
In Zusammenarbeit mit der KTI
Energie
Swiss Competence Centers for Energy Research

Motivation for TP/LCM

- Time for infiltration, under constant pressure, unidirectional, with no preform deformation...

$$t = \frac{\eta (1 - V_f) L^2}{-2 K \Delta P}$$





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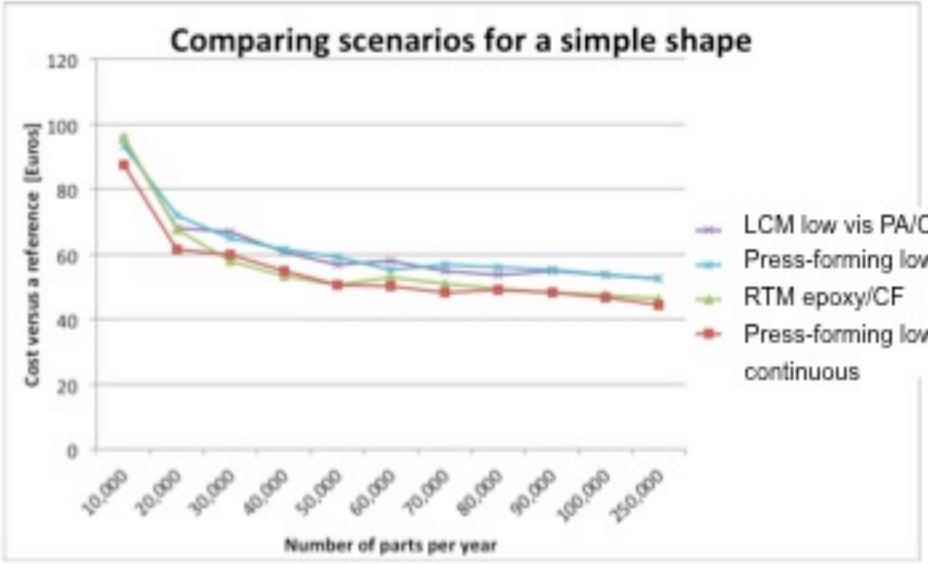
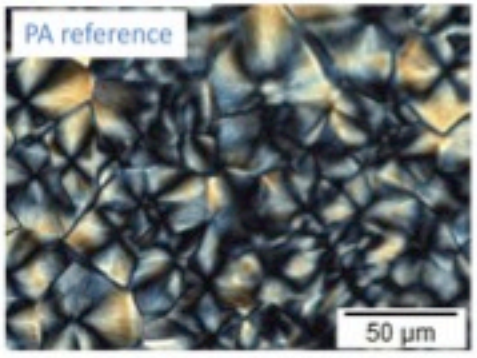
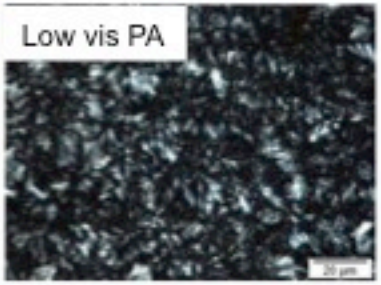
Low viscosity PA systems, 10-15 Pa.s

- Potential for rapid processes, mechanical properties similar to reference PA
- Cost comparable to that of RTM processes, suitable for complex shaped parts







Work in progress/planned

Investigate the process window for LCM with PA:

- Capillary effects and solidification in presence of the reinforcement,
- Set-up of a laboratory tool for PA-LCM
- Optimization of processing parameters (temperatures, pressure, consolidation time, heating/cooling rates, effects of temperature gradients)
- Evaluation of preforming strategies, distribution grids, or varying permeability media (tow and low Vf mats)
- Definition of a case study from automotive related applications
- Cost/LCA analysis of process versus traditional RTM

How to improve properties of composites ?

Prof. André Studart
Laboratory for Complex Materials
ETH Zürich

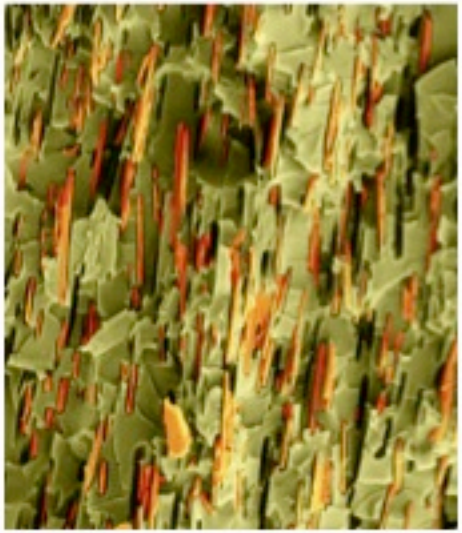
Dr. Rafael Libanori

Ms. Madeleine Grossman

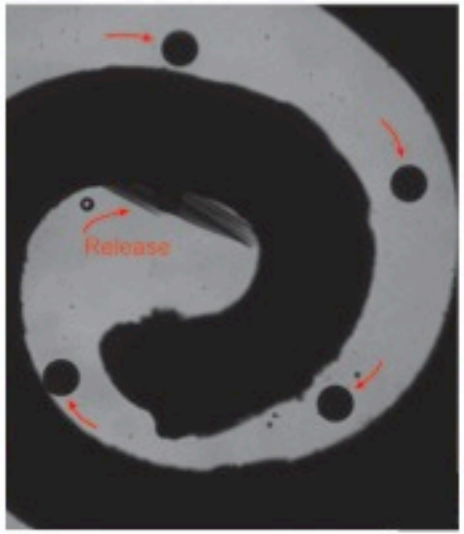
Brittle & susceptible to impact damage

We create **composite materials with complex hierarchical architectures**. These materials are exploited to deepen our understanding of structure-property relationships at multiple length scales

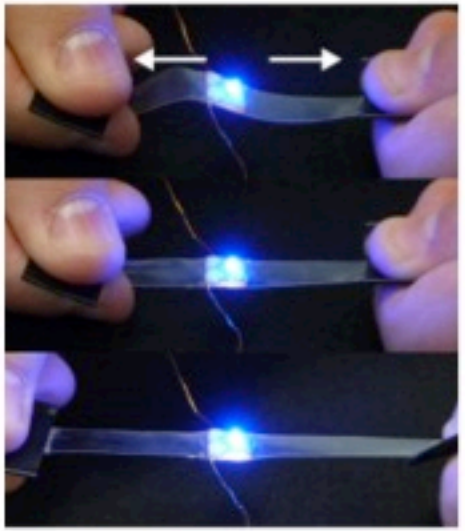
COMPLEX Materials



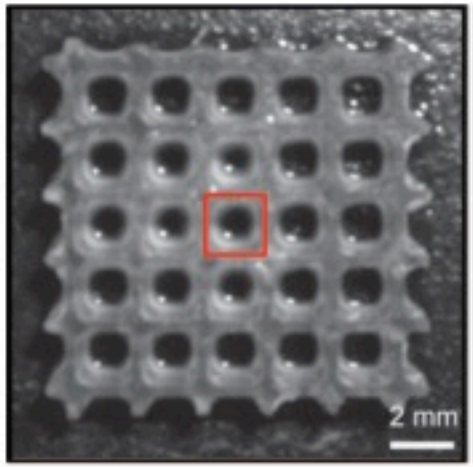
Bioinspired composites

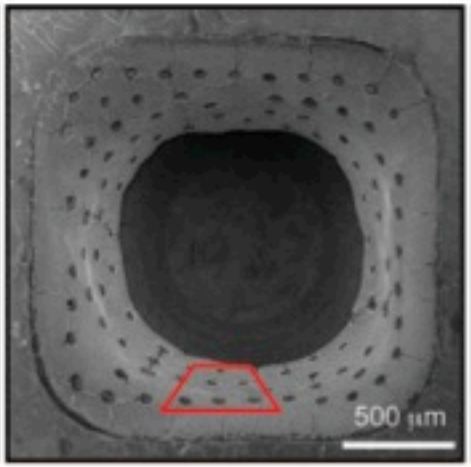


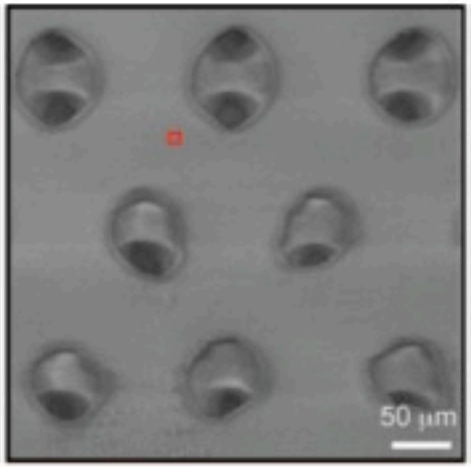
Functional microcapsules

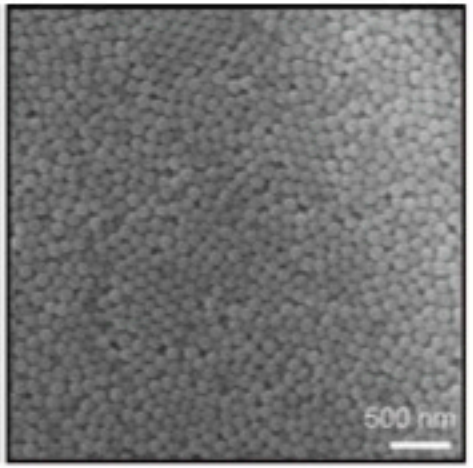


Functional materials



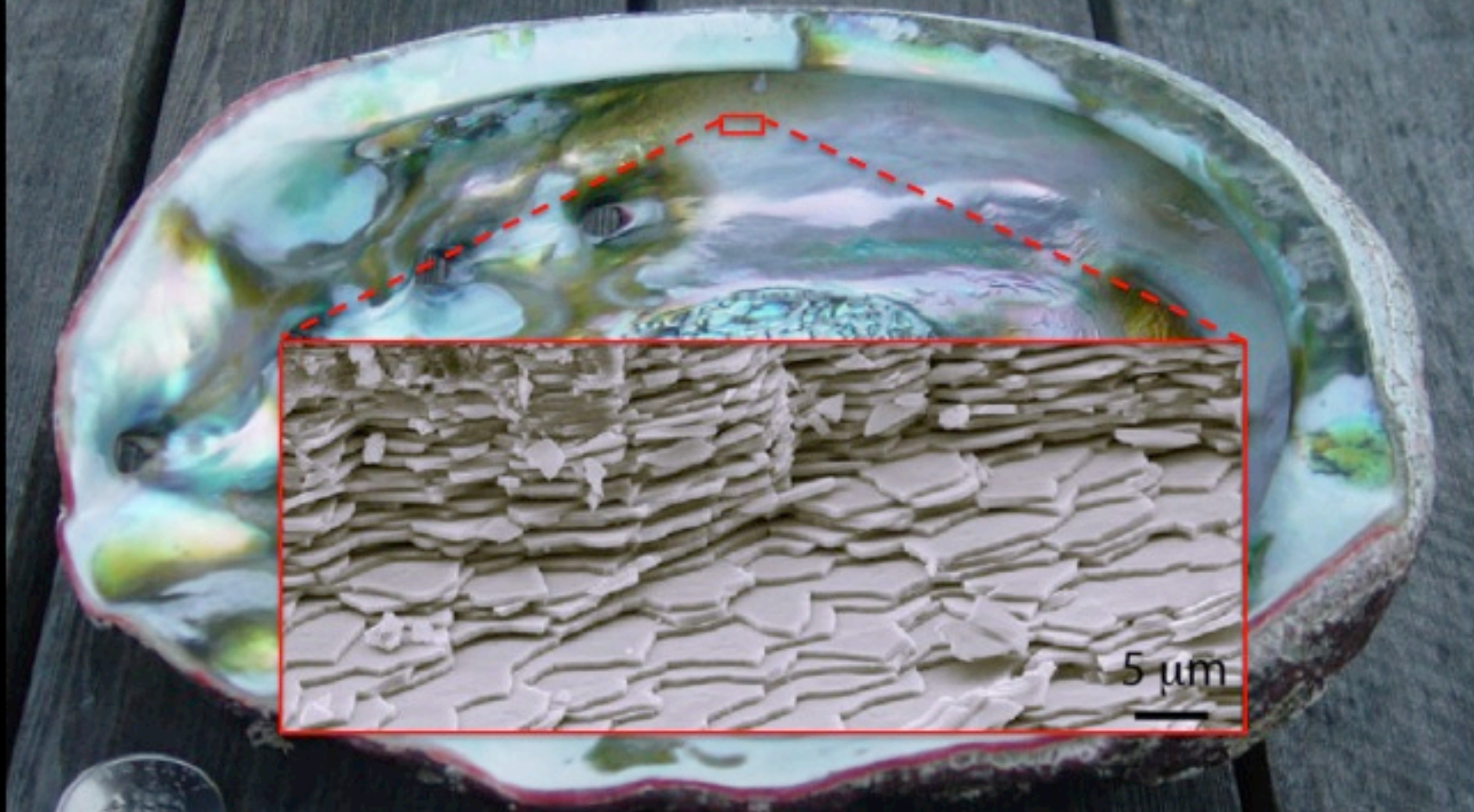






Hierarchical porous materials

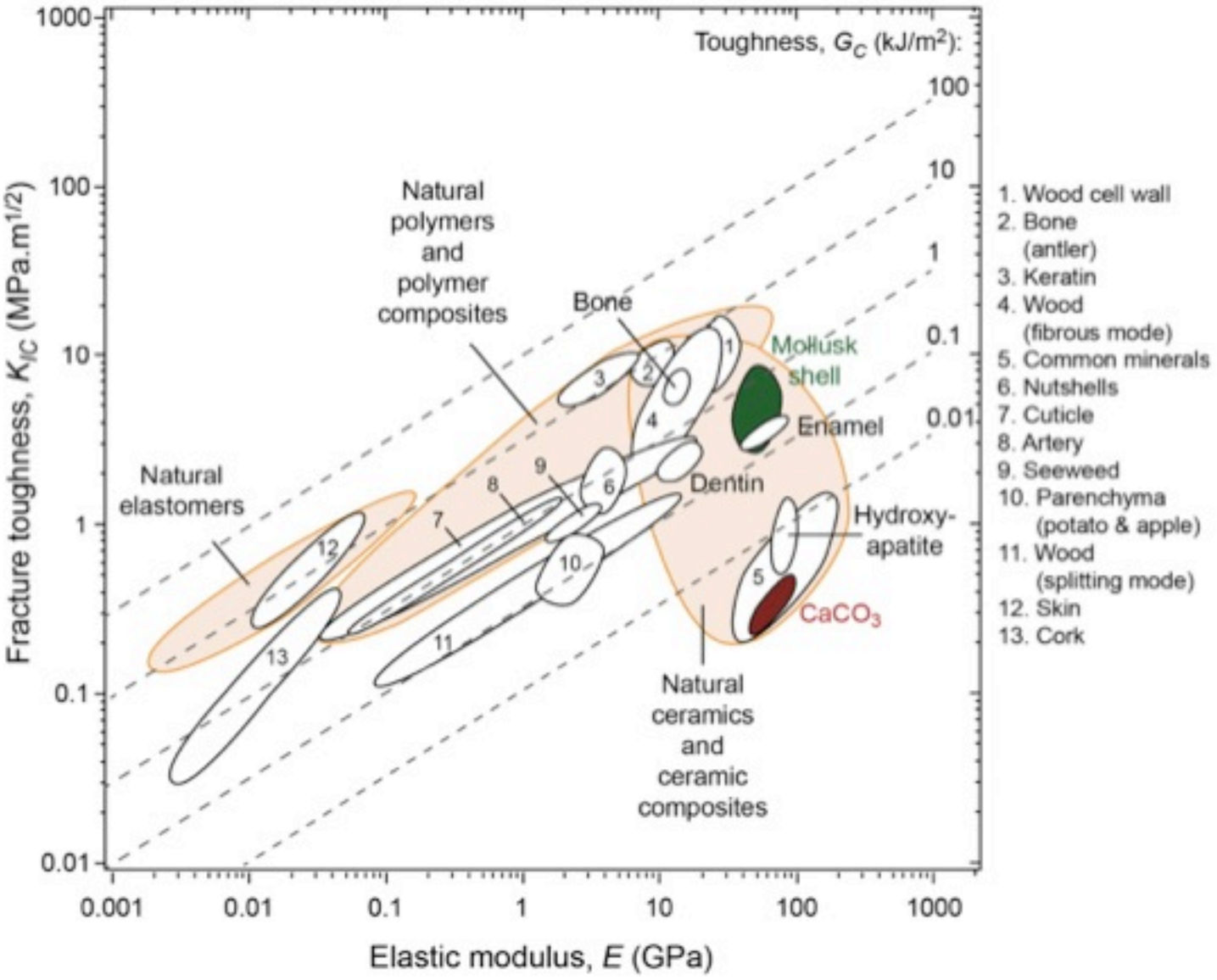
Nacre: Tough composite in nature



http://en.wikipedia.org/wiki/Abalone

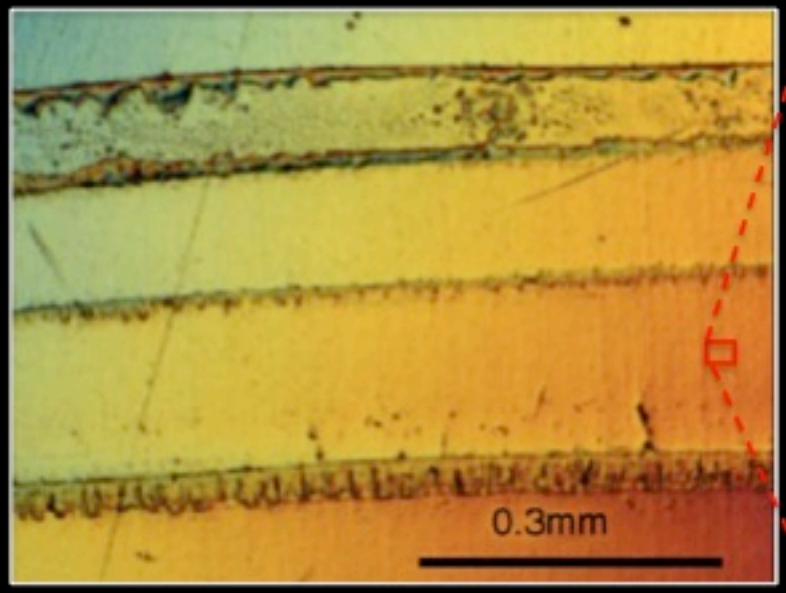
Abalone shell

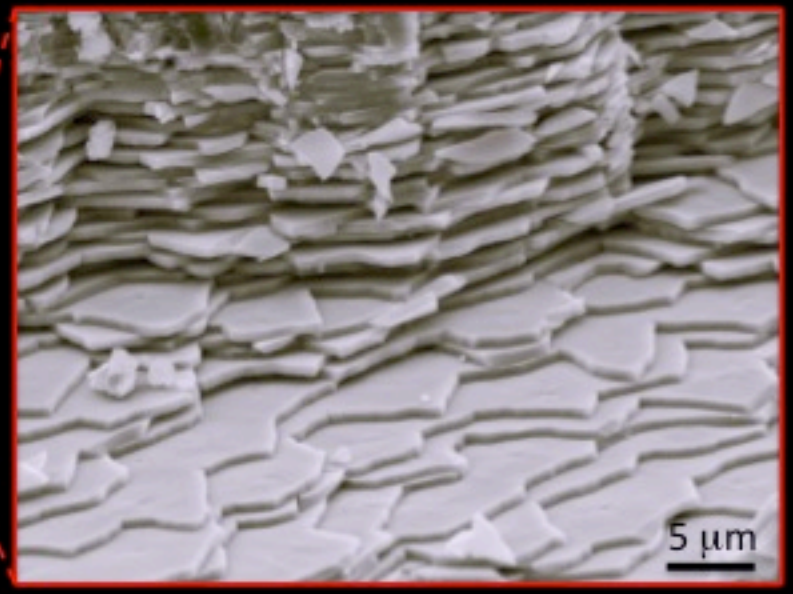
Toughness through micro-/nano structural design

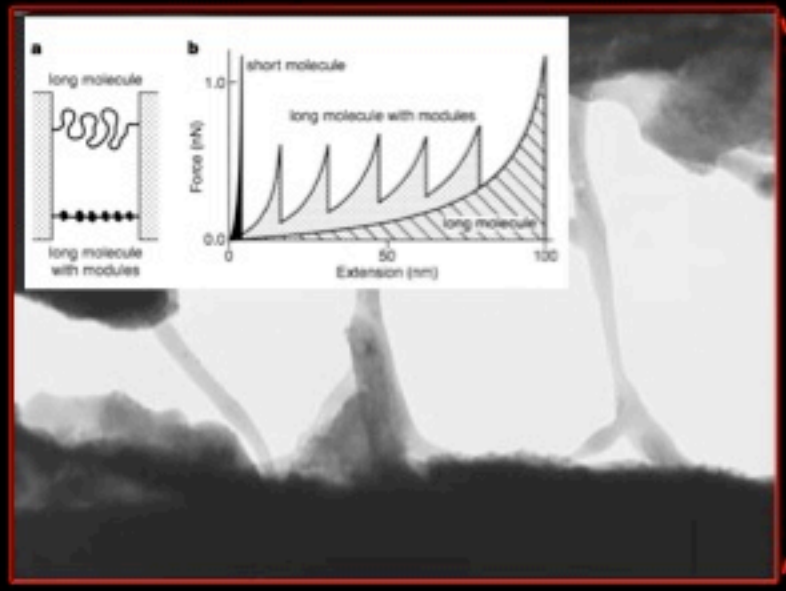


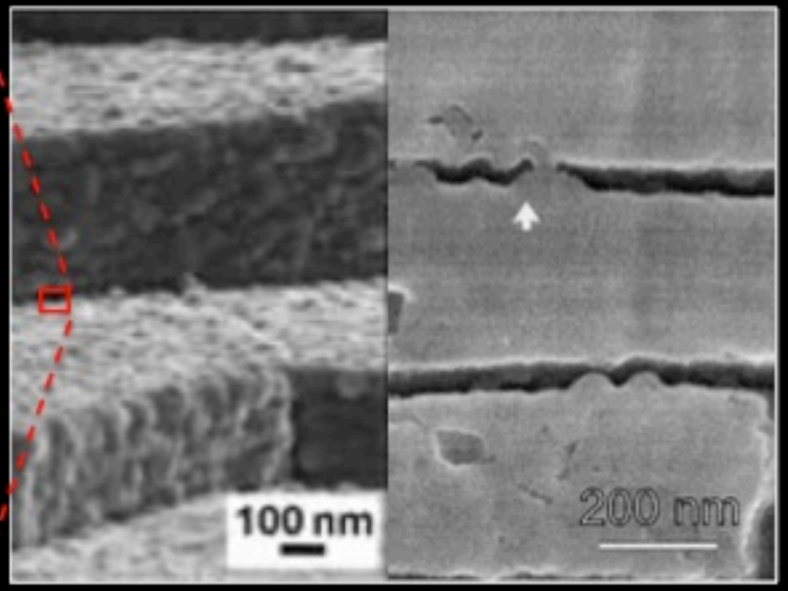
Studart, *Advanced Materials* 2012, 24, (37), 5024

Nacre







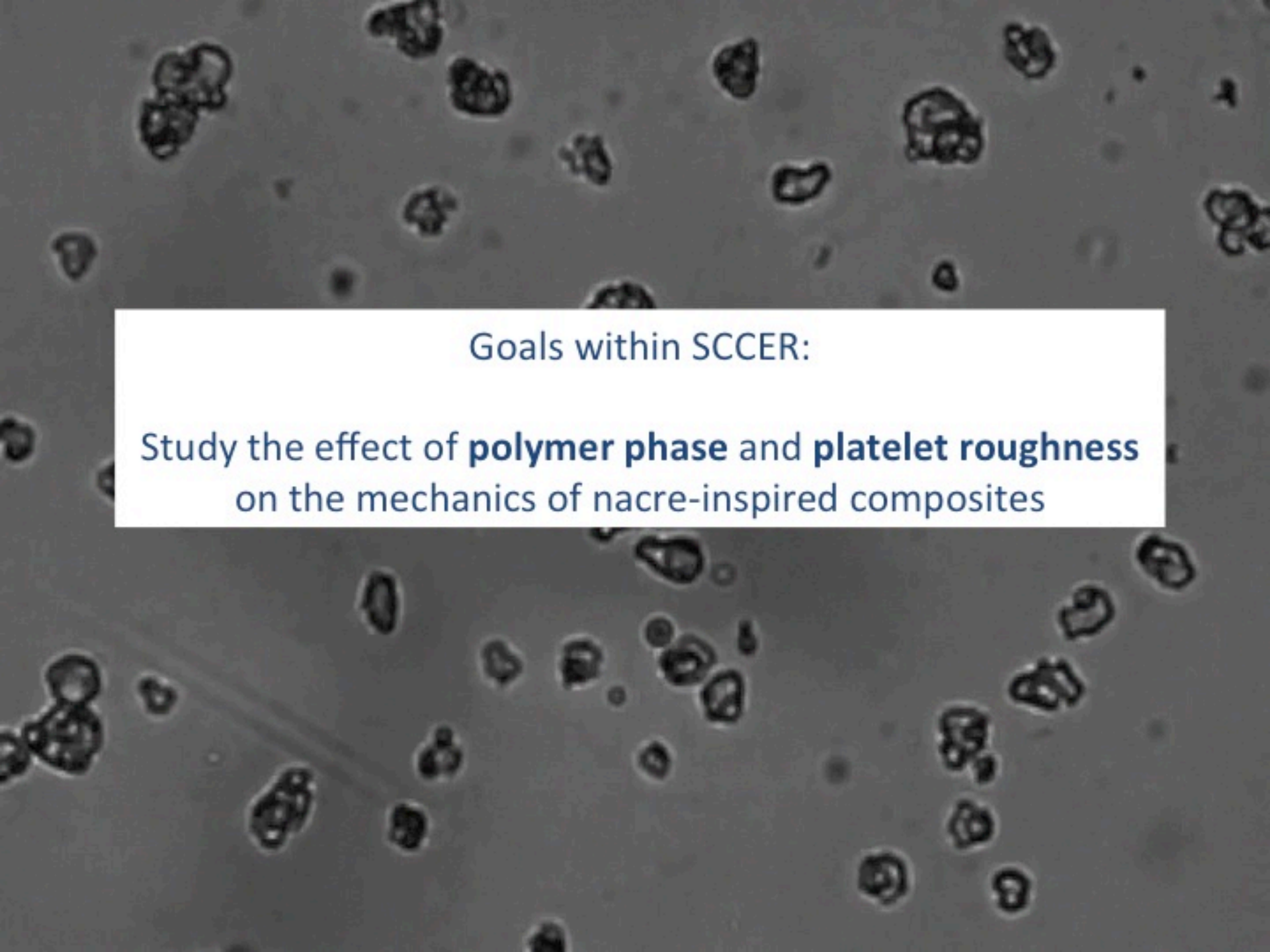


Menig, R. et al, *Acta Mater.* 2000, *48*, 2383

Smith et al, *Nature* 1999, *399*, 761

Oaki & Imai, *Angew. Chem. Int. Ed.* 2005, *44*, 6571

Wang et al, *J. Mater. Res.* 2001, *16*, 2485



Goals within SCCER:

Study the effect of **polymer phase** and **platelet roughness** on the mechanics of nacre-inspired composites

How to design composites for thermal efficiencies ?

Dr. Gil Georges
Aerothermochemistry
& Combustion Systems Laboratory
ETH Zürich (Prof. Boulouchos)

Mostly structural parts /
unexploited functionalities

Competences

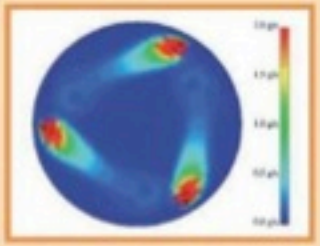
Experimental Research Group

- *Numerical simulation of a hydrothermal flame (Christos Frouzakis)*
- *Miniaturised, optical probe for in-situ measurement of soot concentration and soot temperature in the combustion chamber(Peter Obrecht)*
- *Optical diagnostic of homogeneous, compressed ignition combustion systems (Andreas Escher)*
- *Time resolved records of soot formation and oxydation in diesel engines with an incylinder sampling valve (Pascal Wilhelm)*
- *Source and control of thermo accustic instabilities in premixed combustion (Daniel Fritsche, Marc Füri)*
- *HERCULES - High Efficiency Engine R&D on Combustion with Ultra-Low Emissions for Ships (Kai Herrmann)*
- *Ultra-High-Energy-Density converter for portable energy (Bruno Schneider)*

FUNDAMENTALS

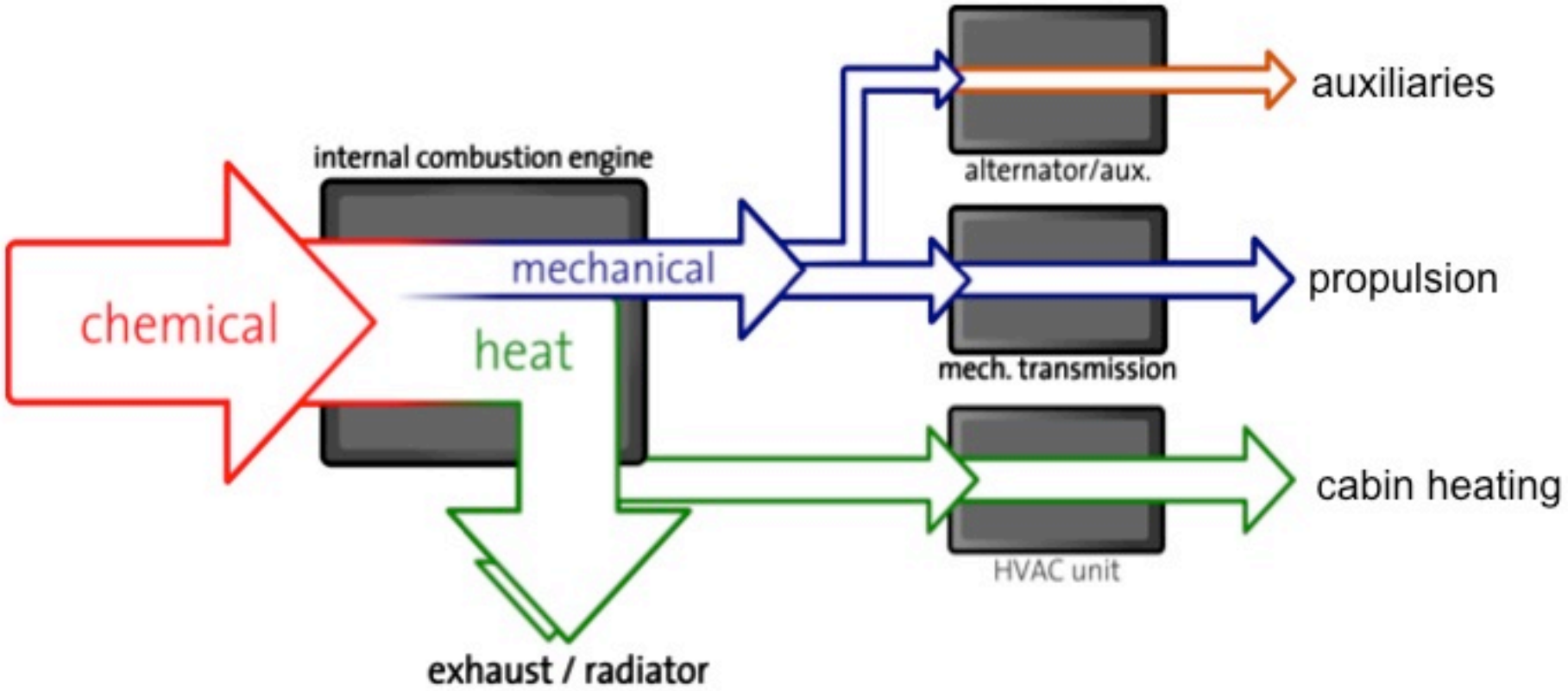
APPLICATION

Numerical Research Group



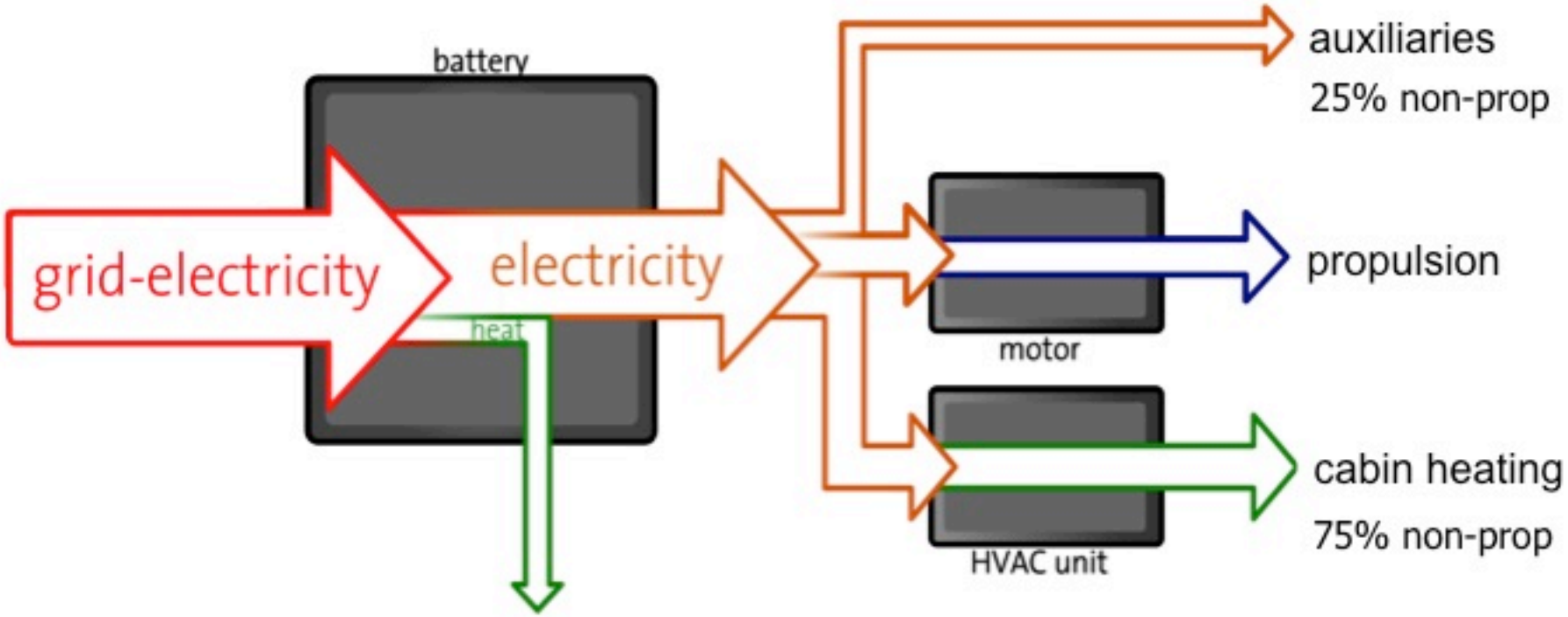
- *Direct numerical simulation of reactive flows (Christos Frouzakis)*
- *Entropic Lattice Boltzmann (Ilya Karlin, Nikolaos Prasianakis)*
- *Large-Eddy simulation of turbulent, non-isothermal jets with variable densities (Gianmarco Pizza)*
- *Simulation of turbulent combustion with RANS/CMC scheme (Yuri Wright)*
- *Modeling and minimising of diesel engine originated emissions by bioinspired algorithms (Peter Obrecht)*
- *Fast calculation of row soot emissions in a diesel engine in steady-state and transient operation (Patrick Kirchen)*
- *Predictive calculation of self ignition and flame propagation in natural gas engines (Christian Lämmle)*
- *Energie Navigator (Faabrizio Noembrini, Aikaterini Kartsoni)*

Provision of auxiliary power in conventional powertrains



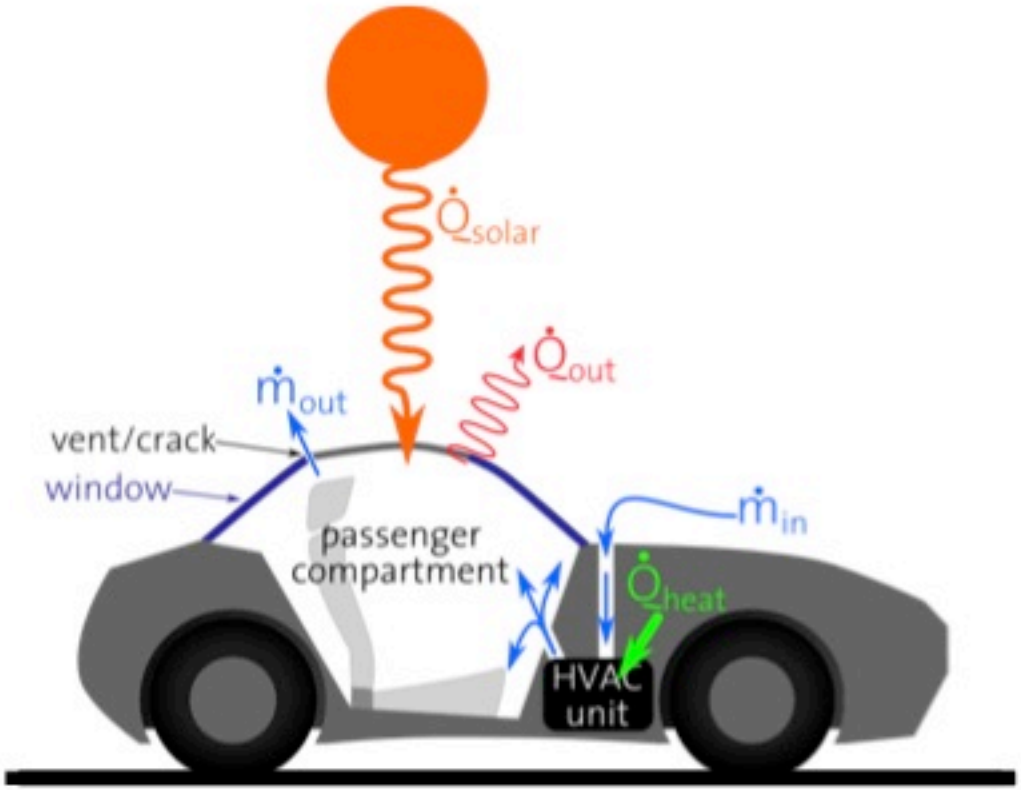
1) heating energy is «free» → no impact on range
2) auxiliary power from mechanical output → better load-point

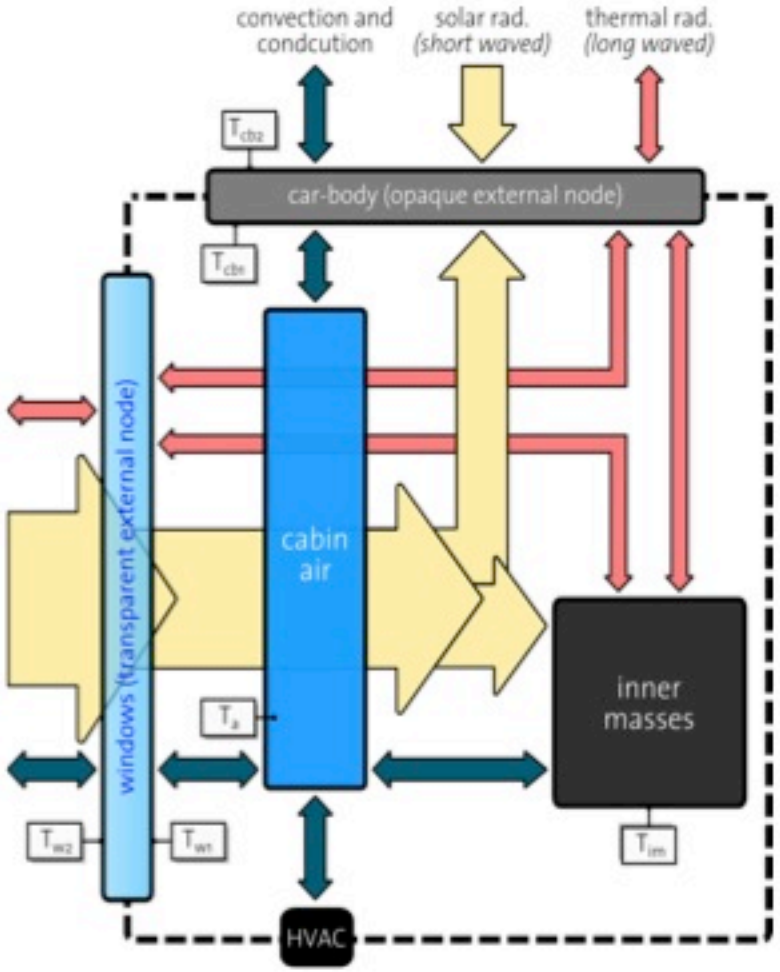
Provision of auxiliary power in electric vehicles



1) heating in competition for battery energy → range decimated
2) auxiliary power increases battery current → higher losses

Thermal model of a passenger cabin





Source: Investigation of the propulsive and non-propulsive loads in passenger cars with emphasis on electric mobility, G. Georges, ETH-Diss Nr. 22057

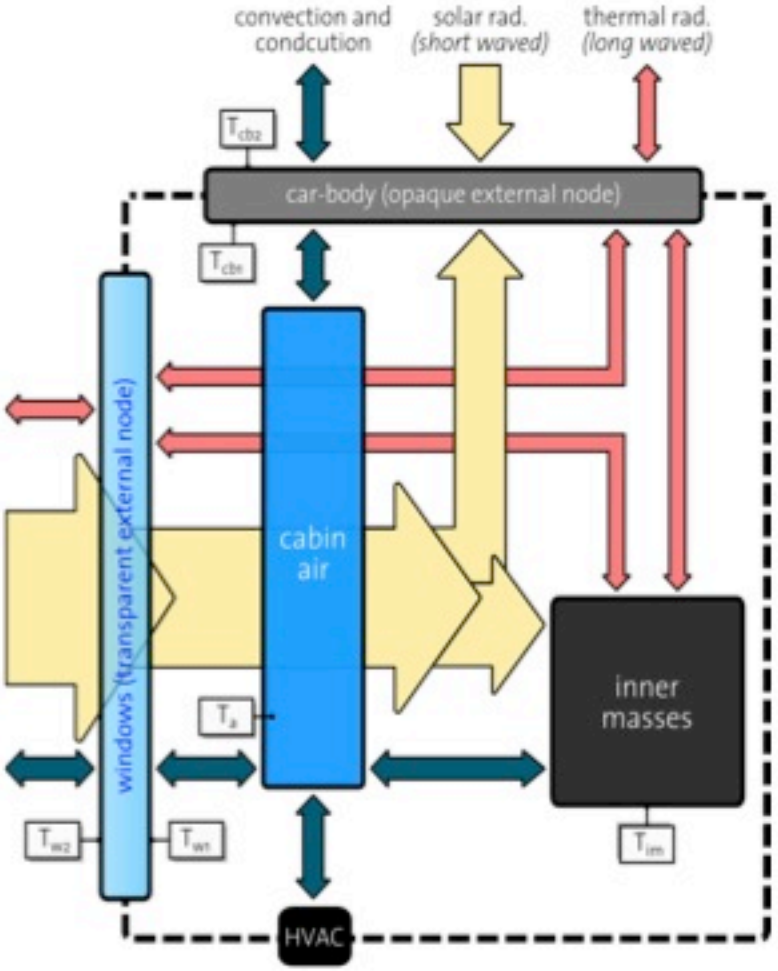
Thermal model of a passenger cabin

4 thermally interacting bodies:

- Cabin air → exchanged via HVAC
- Car-body (opaque)
- Windows (transparent → sunlight)
- Inner masses (seats, ...)

The inner masses have:

- A high heat-capacity, in particular much higher than the cabin air
- No direct path to exchange heat with the atmosphere

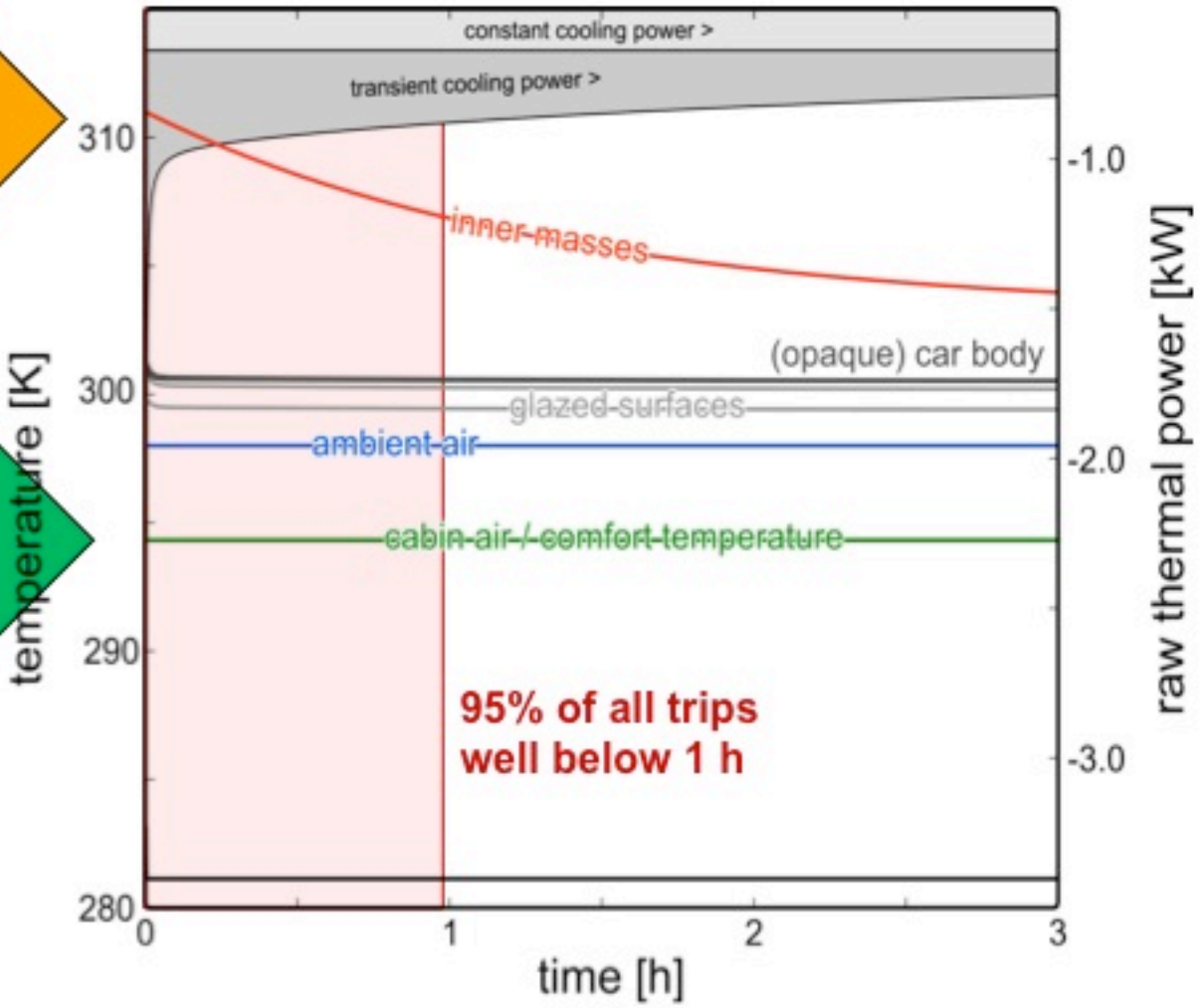


Source: Investigation of the propulsive and non-propulsive loads in passenger cars with emphasis on electric mobility, G. Georges, ETH-Diss Nr. 22057

Transient heating/cooling dominates

Inner masses cool down slowly

Cabin air drops to targeted comfort temperature within minutes



Example for a Golf-type car driving away on a 2014 «summer» day

Outlook

- **Experimental validation with EMPA-ICEL**
- **Application of model to different climates**
  - «global» importance of HVAC load
  - Need for region-specific HVAC solutions?
- **Application of model to other vehicles (boundary conditions)**
  - Different passenger cars (mini/city ... SUV)
  - Commercial vehicles → in particular busses
- **Co-simulation with powertrain → hybrid electric systems**
  - Advanced energy management strategies
  - Advanced energy harvesting methods
- **Assessment of effect of different composite materials on heat capacity of inner masses and thermal properties of the vehicle**

Our bridge to industry

Dr. Christian Fischer
BComp

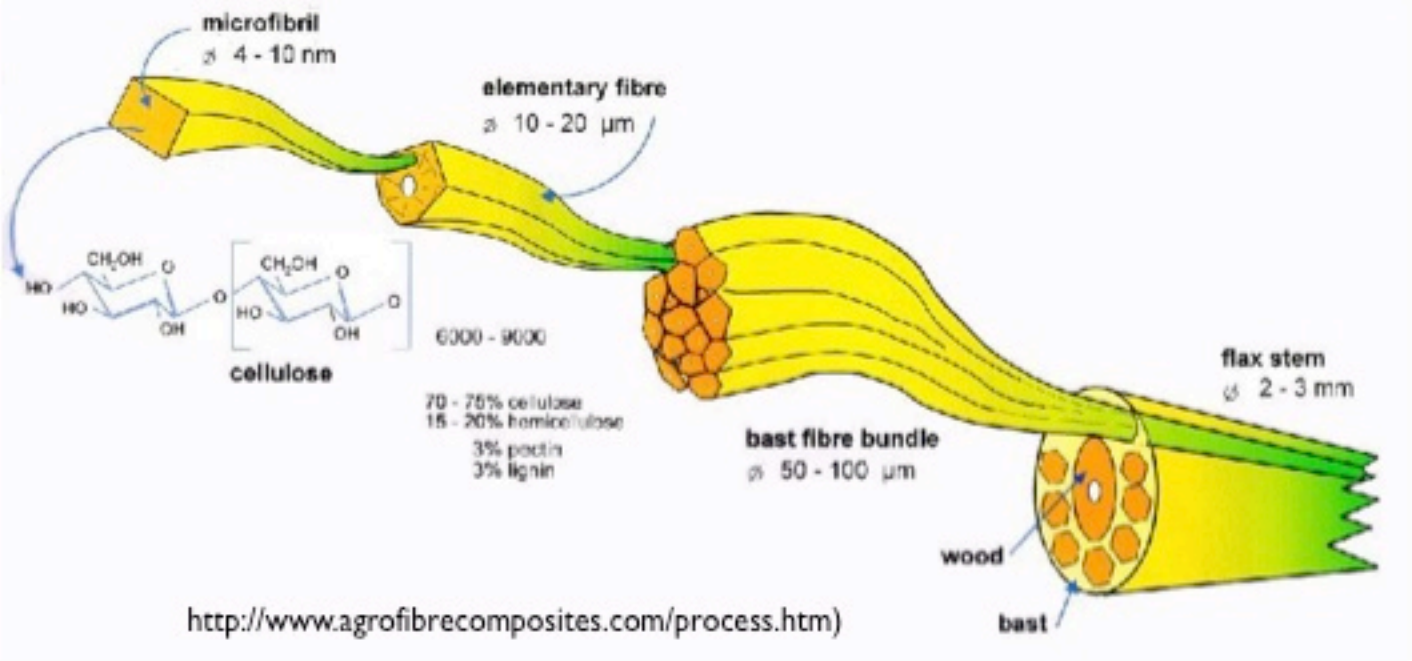
Bcomp®

Bcomp @ SCCER
11.9.2014

Natural fibre composite solutions

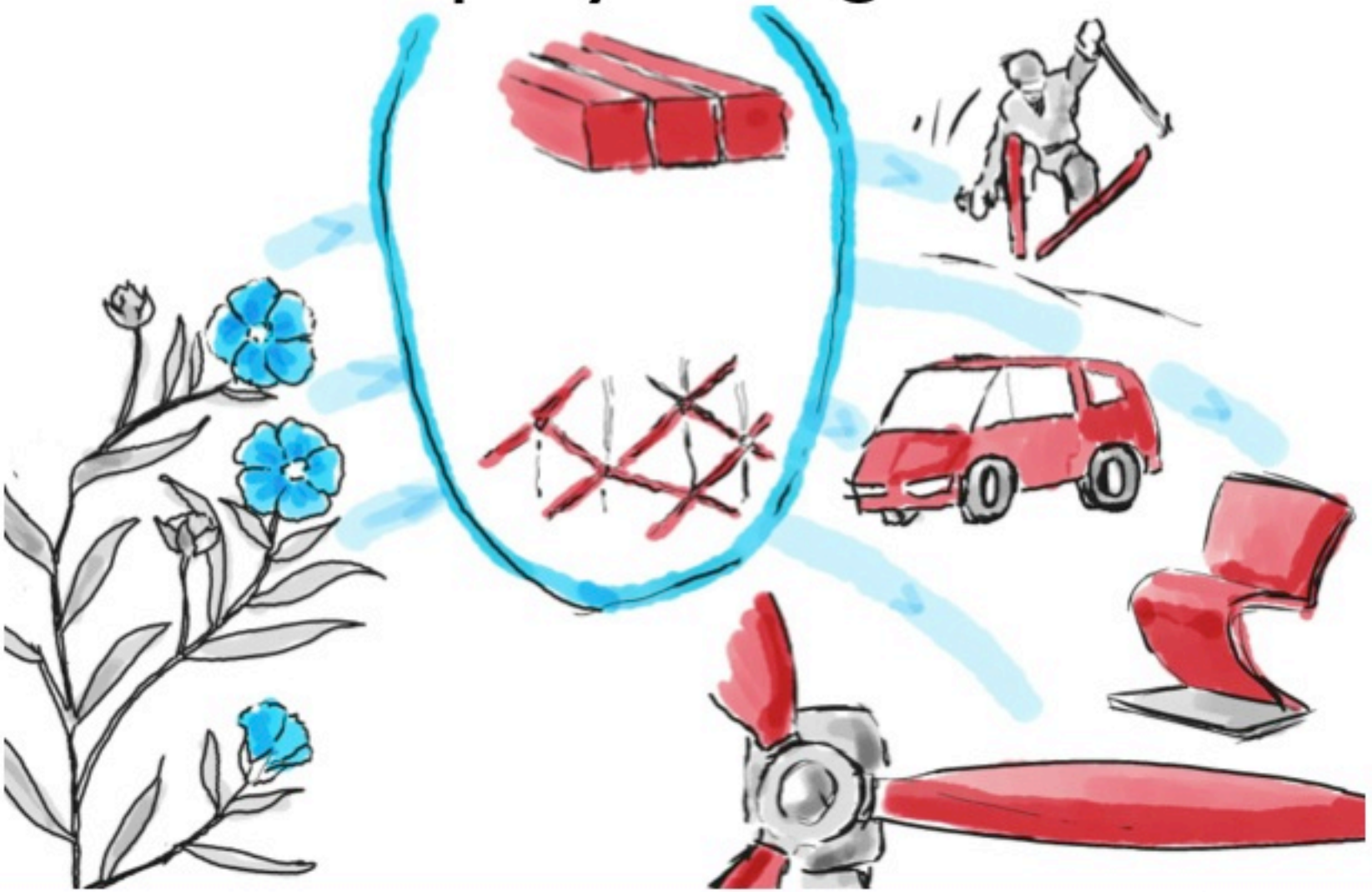
Play naturally smart

Hierarchical flax stem



Bcomp®

Company background



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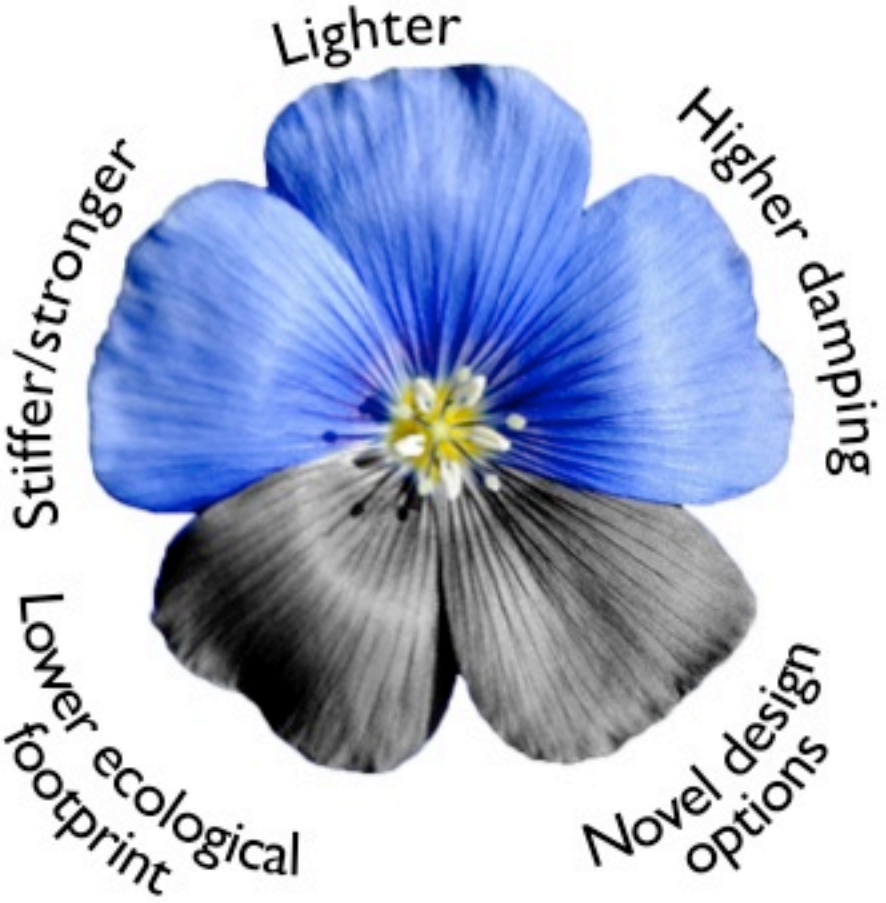
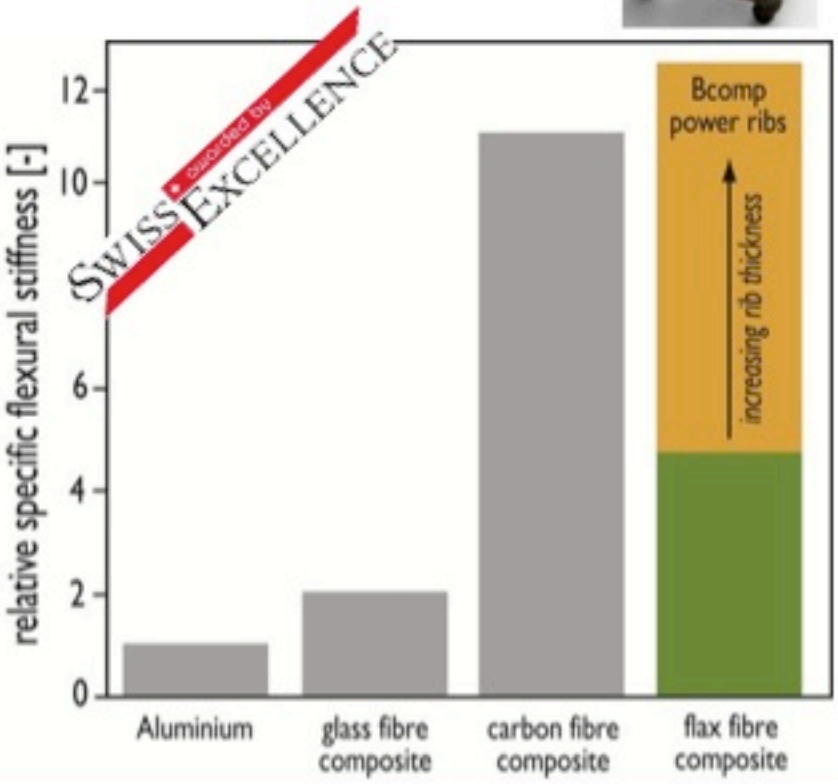
USPs

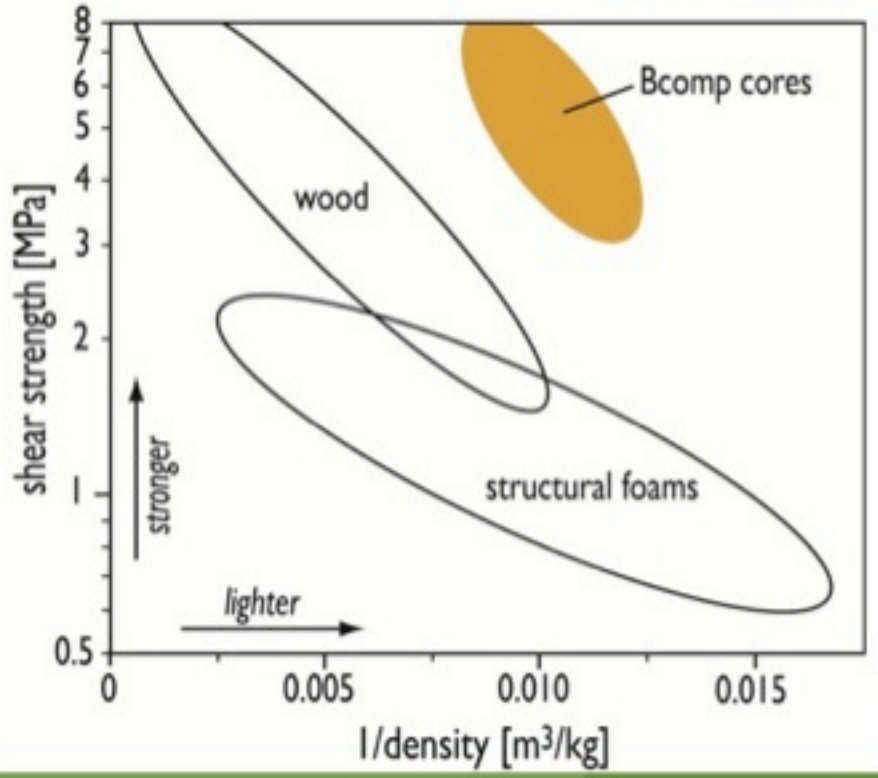

Lighter
Higher damping
Novel design options
Lower ecological footprint
Stiffer/stronger

Bcomp technologies

power ribs
patented



bCores
patented



Bcomp®

Product portfolio

bCores

- Skis
- Snowboards
- Surf
- Kiteboards
- Instruments

ampliTex

- Sports & Leisure
- Design & Furniture
- Music instruments
- Mobility

powerRibs

- Bicycle frames and components
- Mobility
- Space and Aerospace
- Cable cars

Our bridge to industry

Mr. Stève Mérillat
CC Schweiz

CC Schweiz – National Thematic Network

Goal

Benefit for swiss industry, especially SME‘s through innovation und promotion of joint work with universities and institutes

CC SCHWEIZ

In cooperation with the CTI

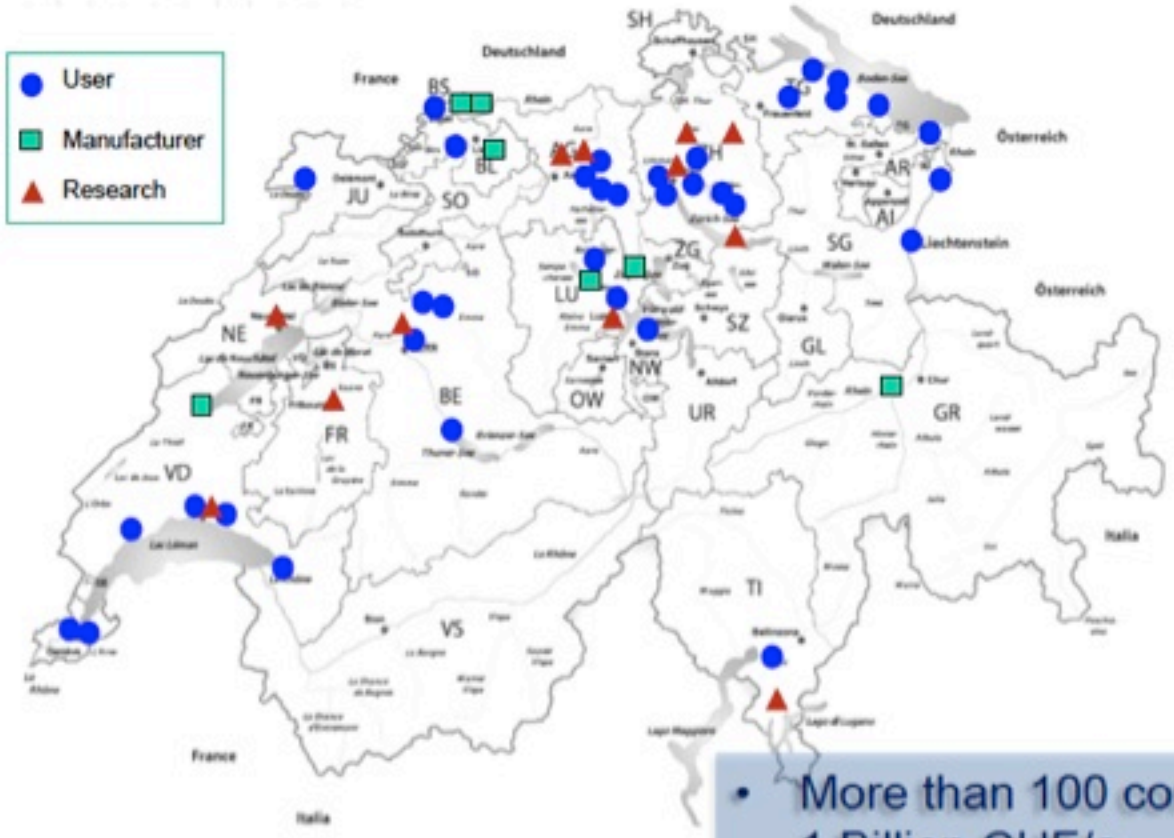
KTT-Support
National thematic networks

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Swiss Confederation

Commission for Technology and Innovation CTI

Composite – Industy in Switzerland
SAMPE Marktstudie Composites*



- More than 100 companies and approx 1 Billion CHF/a

*Autoren:
Nicolas Eguemann und Jochen Müller (FHNW)

Members CC Schweiz

CC Schweiz today: 24 Members

Our team

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Institute for Polymer Technology
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Prof. Véronique Michaud
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& Polymer Technology
EPFL

Dr. Christian Fischer
BComp

Prof. André Studart
Laboratory for Complex Materials
ETH Zürich

Unique team bridging fundamentals (academics) to applied research (industry)

Many opportunities for synergetic collaboration

In Zusammenarbeit mit der KTI
Energie
Swiss Competence Centers for Energy Research
Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra
Kommission für Technologie und Innovation KTI

Thank you !