Development of biobased hybrid composites using novel technologies



JULY 24–27, 2018

ISBBB 2018 Circular Economy for Bioproducts Innovation

15th International Symposium on Bioplastics, Biocomposites and Biorefining

Guelph, Canada

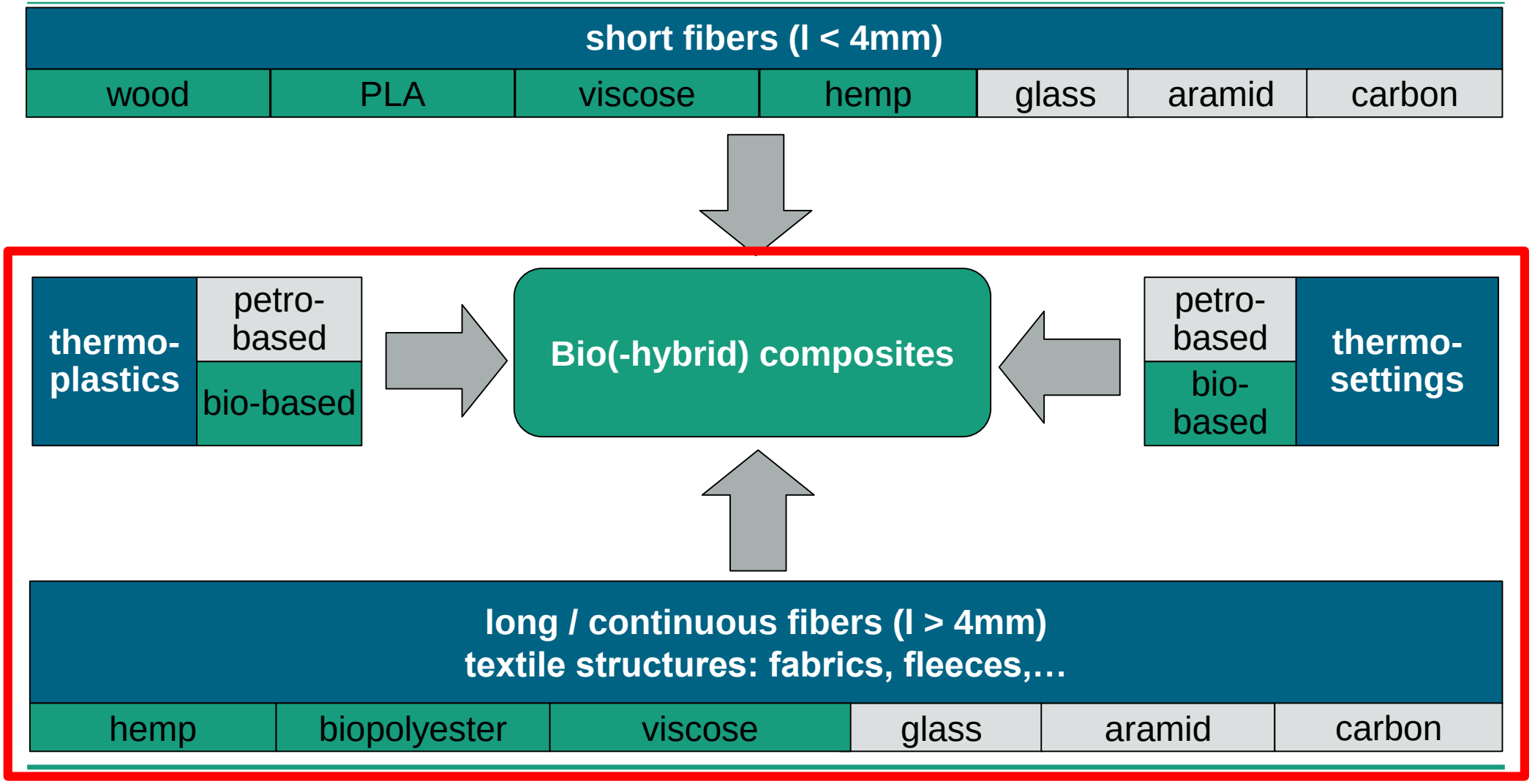
July 24 – 27, 2018 in Guelph

Source: H.-J. Endres, T. Koplin, C.Habermann, *Kunststoffe*, **2012**

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Biobased hybrid composites
Selected materials



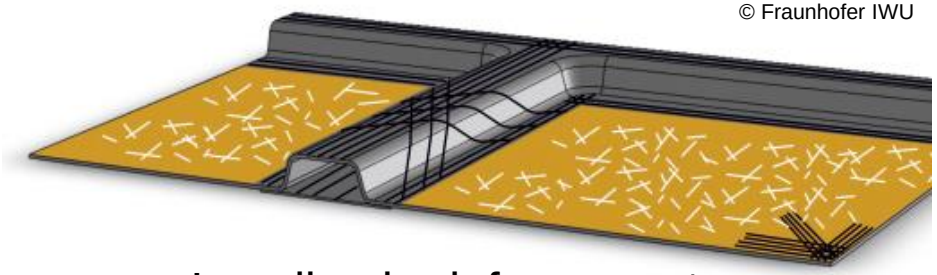
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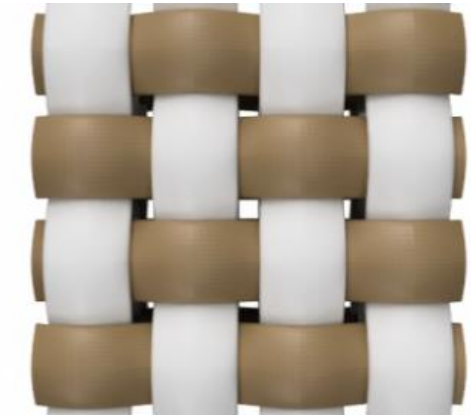
Biobased hybrid composites



Sandwich-structure



Localized reinforcement

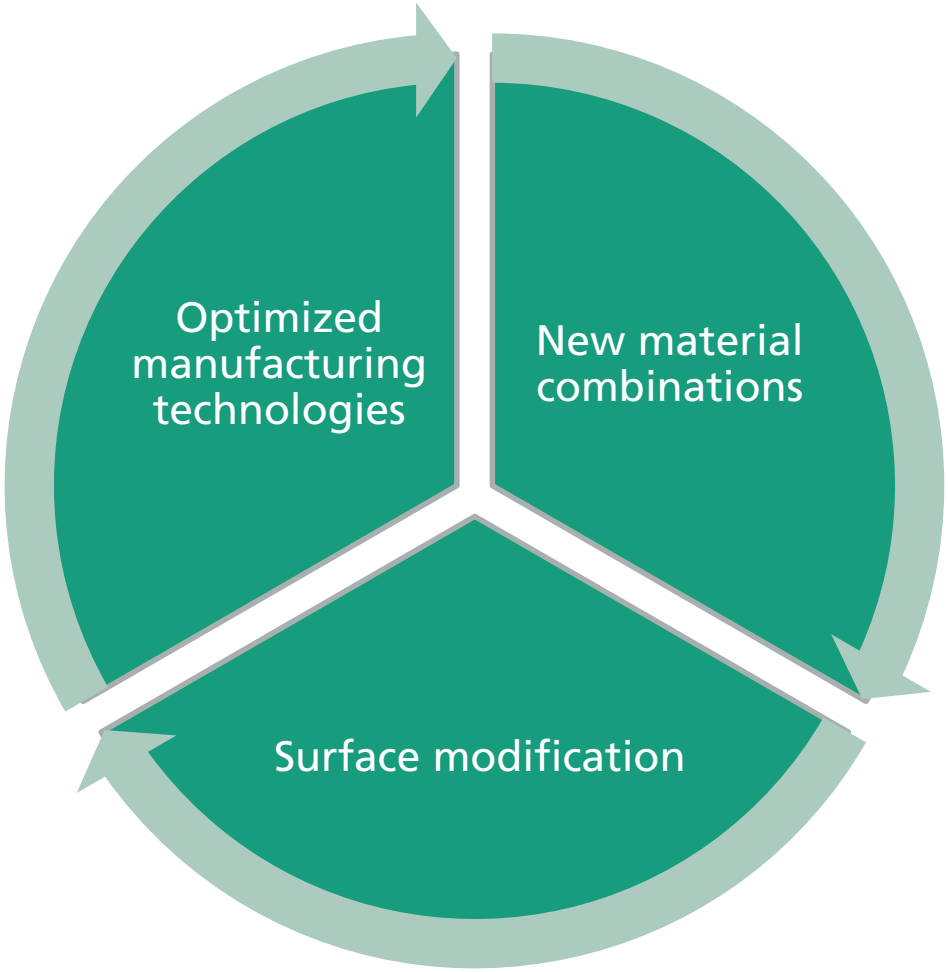


Hybrid technical textiles

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Biobased hybrid composites
Outline



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Biobased hybrid composites
Selected technologies



Fiber spraying facility



Weaving technique &
vacuum infusion / hot pressing

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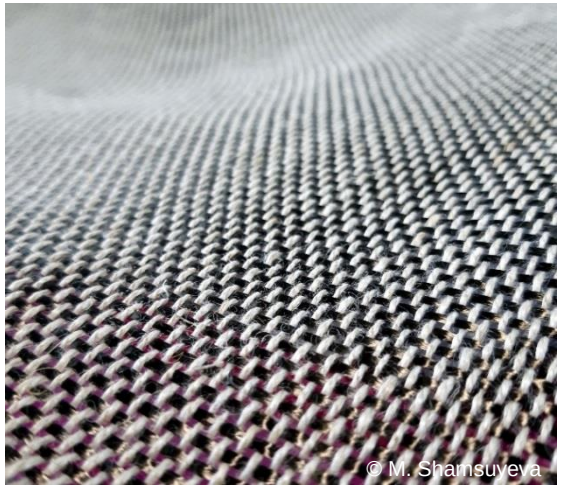
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Biobased hybrid composites
Hybrid textiles for composites

- Types of textile weaves and fiber combinations are selected according to the requirements of the product
  - Anisotropy
  - Load-optimized fabrics
  - Multi-layer and spacer fabrics
- Exemplary textile weaves



flax fabric



flax-/carbon fabric



Double-rapier machine with Jacquard technology

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Biobased hybrid composites

Hybrid textiles for composites



Hybrid woven fabric made from flax and polyamide 6



Various hybrid woven fabrics

Hybrid textile analytics

- Humidity absorption
- Wettability
- Morphology
- Chemical composition

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Biobased hybrid tailored composites
Fiber-spraying facility

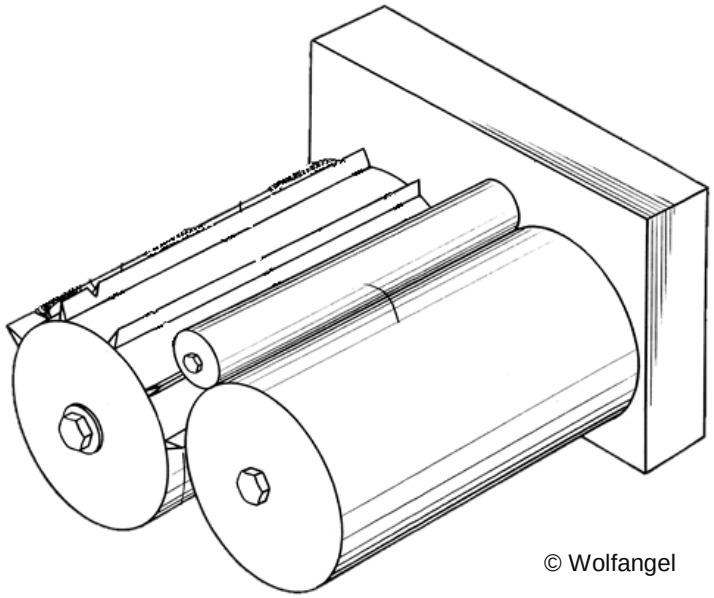


Fiber-spraying facility

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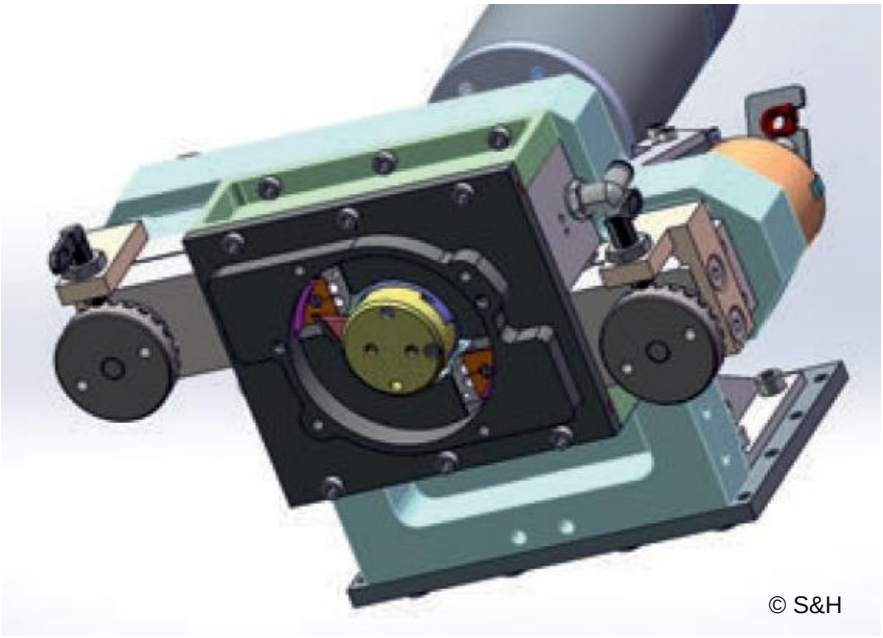
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Adaptation of new technologies
Fiber-spraying facility



© Wolfangel

Conventional fiber-spraying consists of a „chopper“, which **breaks fibers**

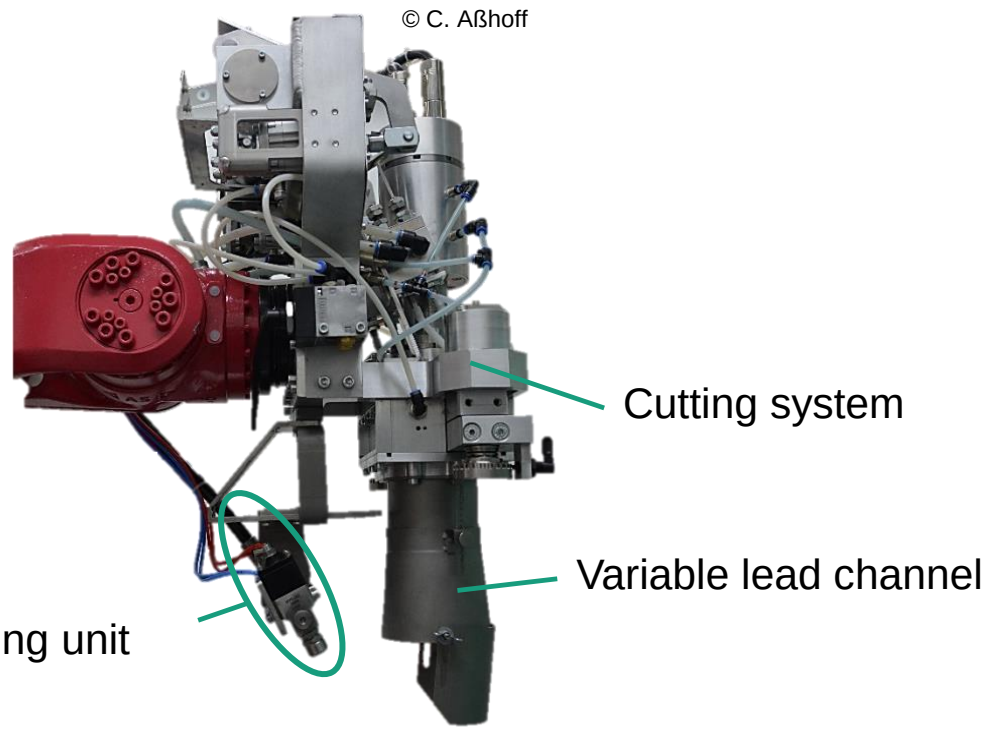


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Optimized cutting system consists of two fixed anvil-blades and one rotating knife, which **cuts fibers**

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Adaptation of new technologies
Fiber-spraying facility



© C. Aßhoff



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Schmidt & Heinzmann
COMPOSITE EQUIPMENT & MACHINERY

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Adaptation of new technologies
Fiber-spraying facility

- Fiber-spraying enables
  - Reproducible cutting of cellulose-based and synthetic fibers
    - 0,5 – 10 cm
  - Simultaneous or alternative processing of up to 4 different fiber types
    - Technical scale
      - 5 – 25 kg/h
  - Variation of a fiber length during the processing



Flax yarn processing

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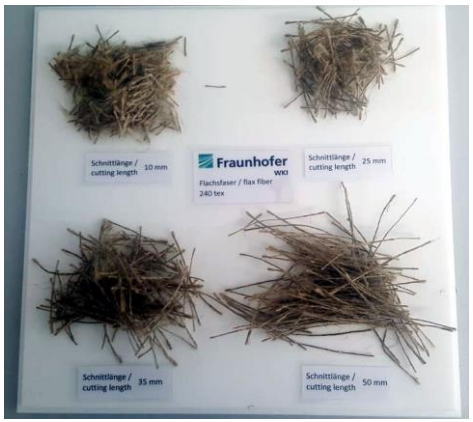
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Adaptation of new technologies
Fiber-spraying facility

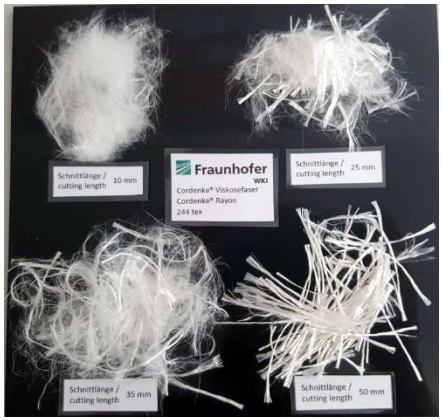
- Possible applications
  - Construction parts with local reinforcement
  - Sandwich structures
  - Reduction of undlation
  - ...



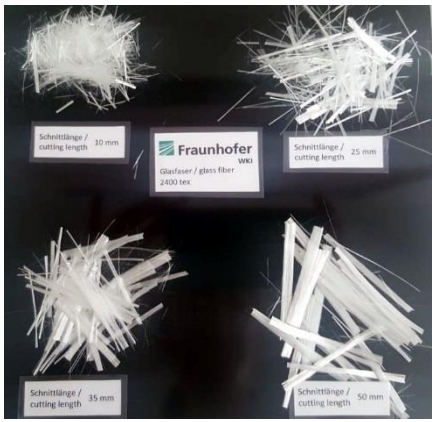
Glass-/flax fiber/reinforced epoxy



Flax (240 tex)



Viscose rayon (244 tex)



Glass (2400 tex)



Carbon (800 tex)

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Fiber-spaying facility

Summary

Processing specifications	Conventional fiber-spraying	Optimized fiber-spraying
Glass fibers	**+**	**+**
Natural, carbon- and hybrid fibers, thermoplastic fibers	**not process-reliable**	**+**
Variable fiber length during the processing	**-**	**+**
Controlled fiber orientation	**limited**	**possible with extention**
Processing of thermoplastic and thermoset matrices	**-**	**+**

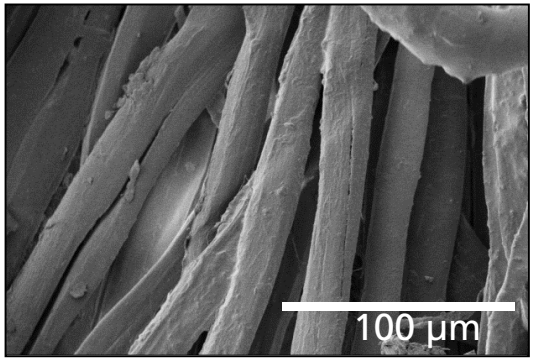
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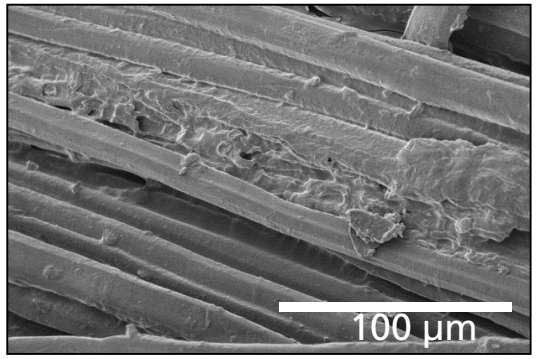
Surface modification of fibers
Research activities

- Surface modification
  - Fiber-matrix-adhesion in composite
  - Improvement of thermal resistance
  - Reduction of humidity absorption
  - Introduction of new functional properties
- Approaches
  - Wet-chemical, physical and complex treatment
  - Polyelectrolyte treatment, mercerization, AD-Plasma, etc.



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Reference flax fibers



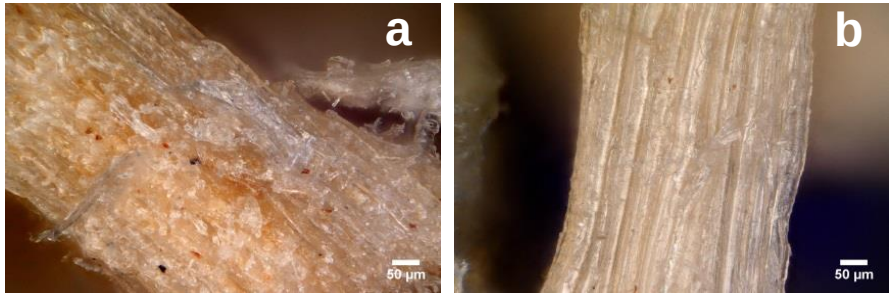
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Flax fibers modified with polyethylenimine

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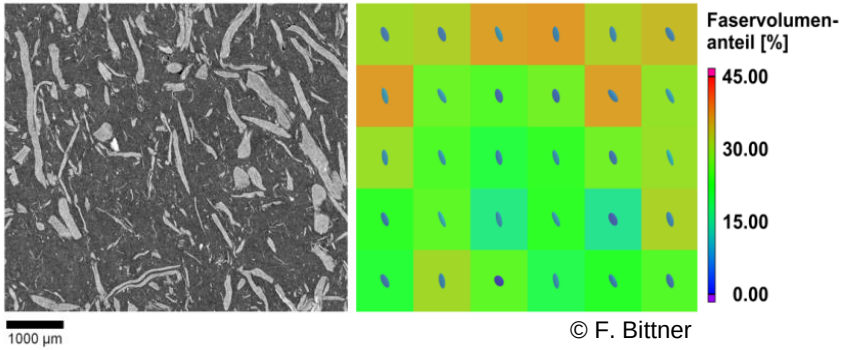
Surface modification of fibers
Fiber analytics

- Fiber analysis before and after integration in polymer matrix
  - Morphology
  - Size distribution
  - Fiber volume fraction in a composite
  - Fiber distribution and orientation in a composite
  - Analysis of chemical composition
  - Hot-stage microscopy
  - SEM/EDX
  - etc.



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Digital microscope image of wood fiber:
a. unmodified b. modified surface (alkali)



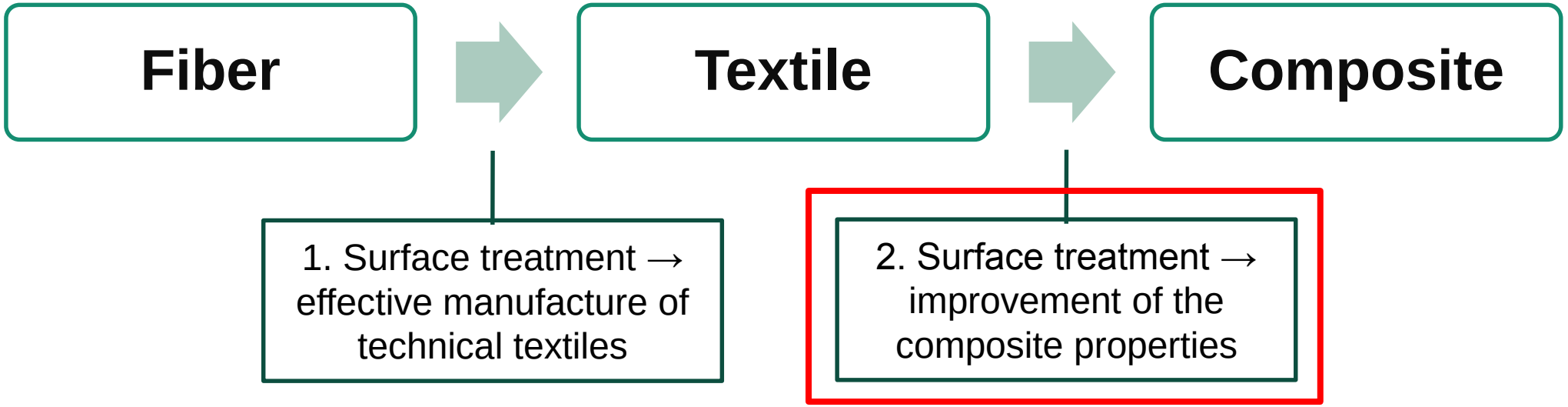
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Short fiber-reinforced polymer composite:
average fiber volume fraction and orientation analysis

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Process schedule



- Several process steps prior to the manufacture of a composite product
- Various process parameters influence the surface of the fibers
  - Morphology
  - Chemical composition
  - Polarity
  - …

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Improvement of thermal stabilty DeFiCoat

Aim

- Improvement of the thermal stability of cellulose-based fibers
- Enhanced mechanical properties, thermal stability and chemical resistance
- Broadening of the application spectrum of biocomposites with natural fibers

Pursued approach

- Coating of the natural fibers with an optimized thermosetting coating
- Coating should act as an isolation between fibers and melted thermoplastics

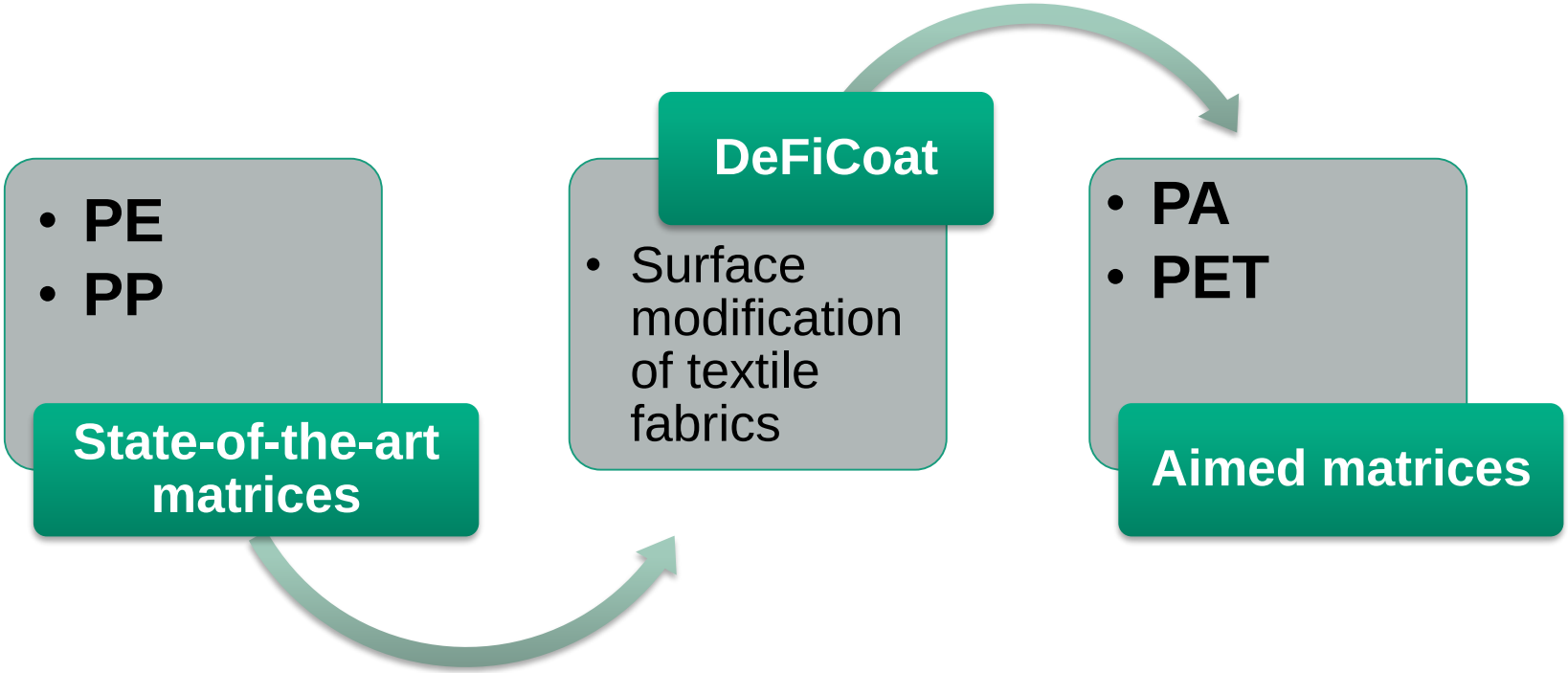
Funding code: 031B0502

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DeFiCoat
Aim

- Currently only certain thermoplastics with lower processing temperature can be used for the manufacture of biocomposites with natural fibers via hot pressing
- Introduction of new thermoplastic matrices is important in order to improve the properties of the biocomposites and open new application fields



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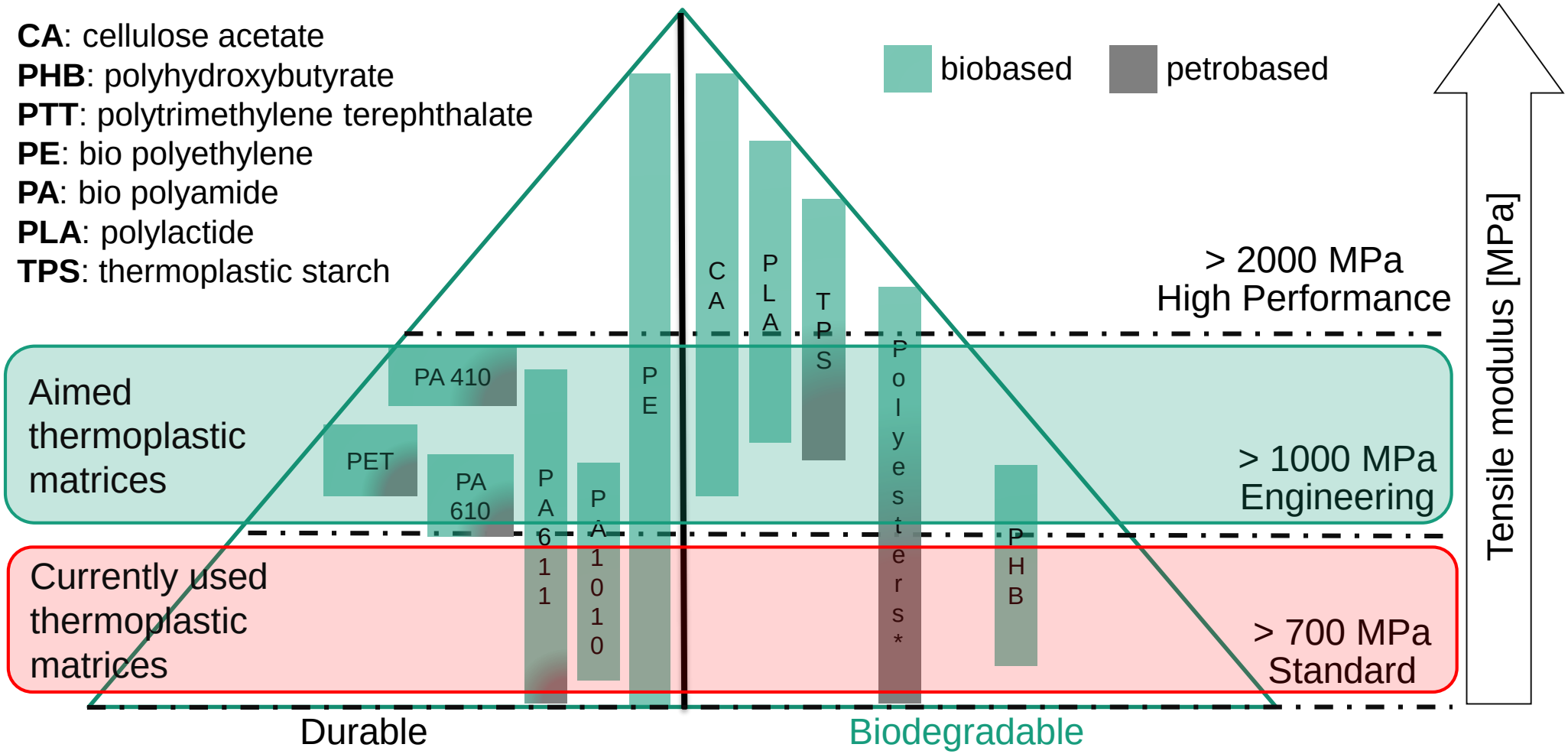
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DeFiCoat

Effective use of new thermoplastic matrices

CA: cellulose acetate
PHB: polyhydroxybutyrate
PTT: polytrimethylene terephthalate
PE: bio polyethylene
PA: bio polyamide
PLA: polylactide
TPS: thermoplastic starch



*: further biodegradable polyesters (PBAT, PCL, PBS)

Source: Fig. adapted from http://biopolymer.materialdatacenter.com/standard/main/
Arranged according to: Tensile Modulus (Range)

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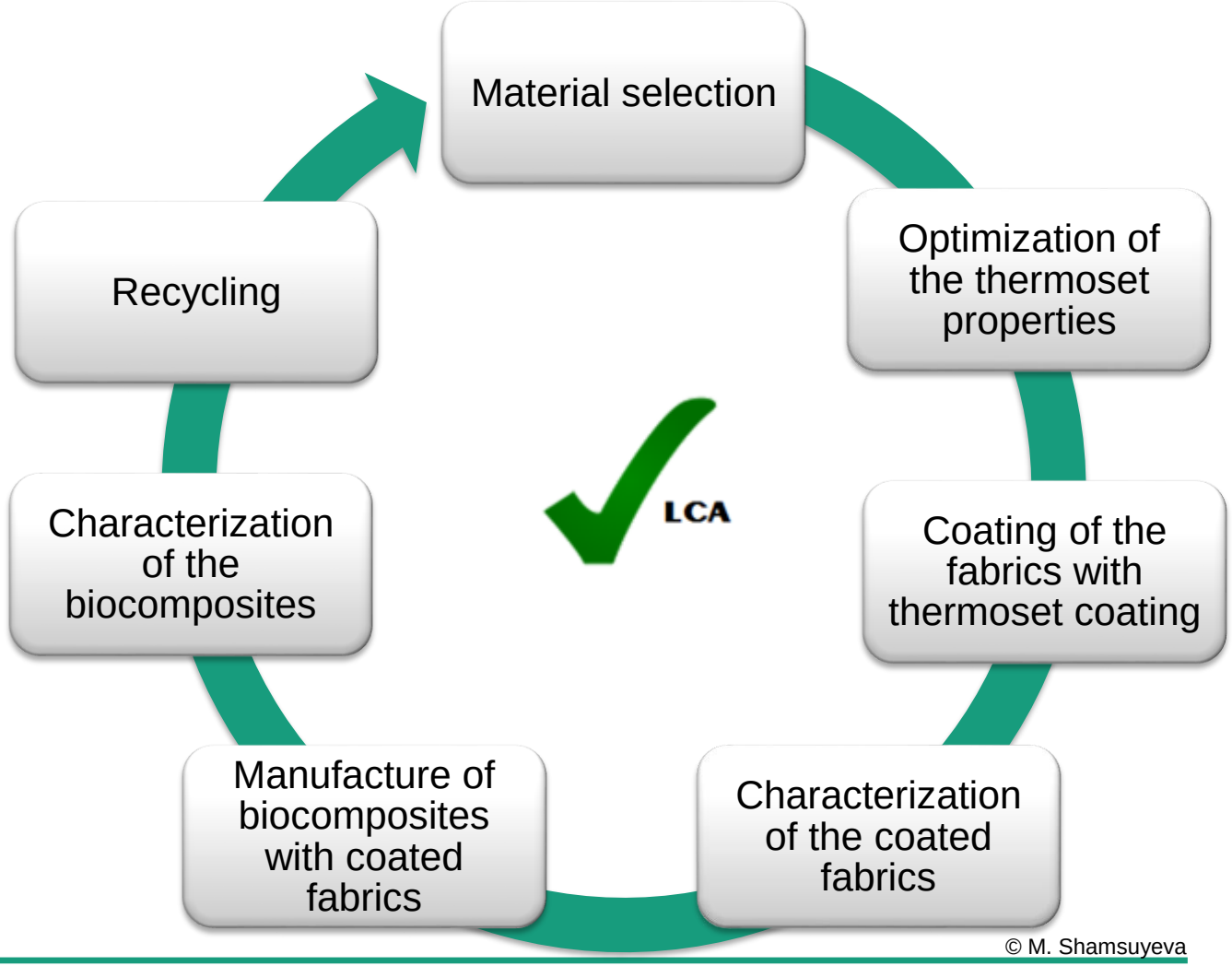
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DeFiCoat
Project course

- Application-oriented research
- Broadening the application field of biocomposites
- Outdoor applications
  - Building constructions
  - Automotive
  - Sport and leisure



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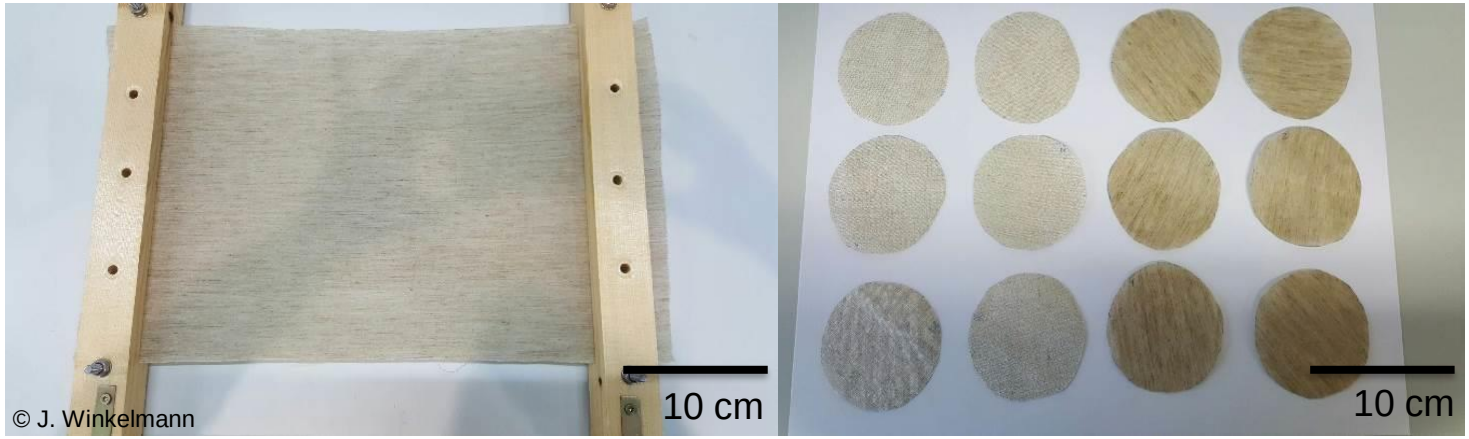
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DeFiCoat
Preliminary results - moisture absorption

- Flax fabrics were coated via spraying with epoxy/acetone solution at lab scale
  - Concentration was varied
- The moisture absorption was measured gravimetrically during several hours
  - 23° C / 50 % RH



- Flax fabrics before coating (left) and coated specimens for moisture absorption analysis (right)

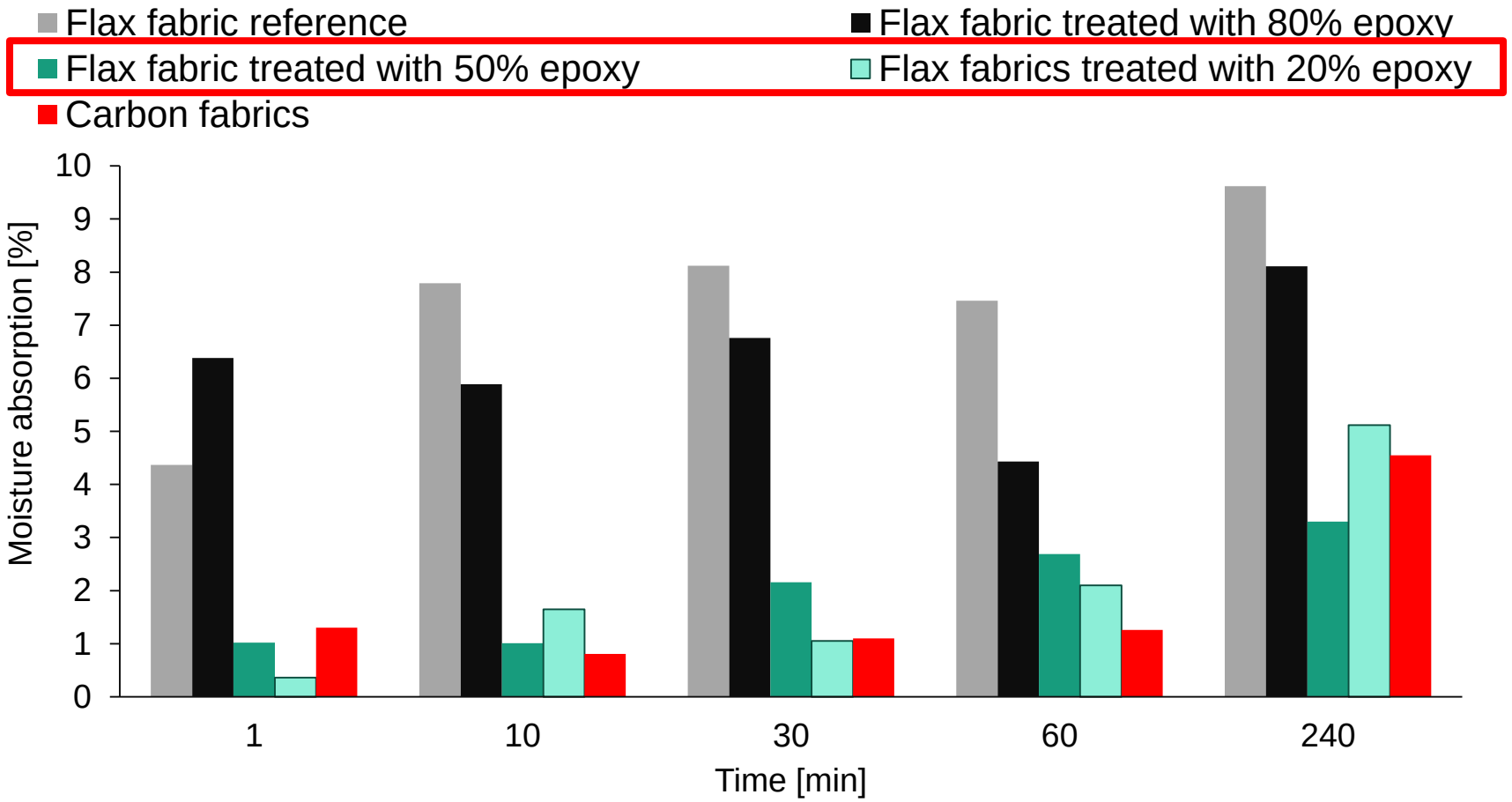
Reinsch, J., Haxter, C., Endres, H.-J., Vorbehandlung von Naturfasergeweben zur Erweiterung ihres Anwendungsspektrums, 12. ThGOT – Thementage Grenz- und Oberflächentechnik gemeinsam mit dem 5. Kolloquium Dünne Schichten in der Optik, Thüringen, 15.03.2017

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DeFiCoat

Preliminary results - moisture absorption



- Coating with 20% epoxy has delivered results comparable with carbon fabrics

Reinsch, J., Haxter, C., Endres, H.-J., Vorbehandlung von Naturfasergeweben zur Erweiterung ihres Anwendungsspektrums, 12. ThGOT – Thementage Grenz- und Oberflächentechnik gemeinsam mit dem 5. Kolloquium Dünne Schichten in der Optik, Thüringen, 15.03.2017

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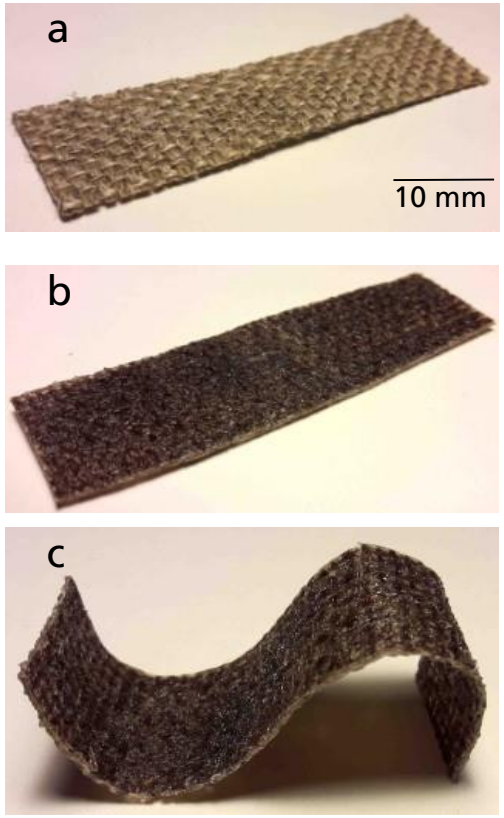
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DeFiCoat
Summary

- Application-specific manufacture of novel high-quality biocomposites for outdoor applications
  - Automotive, construction, sport industry
- International competence exchange
- Support of the young scientists
- Research visit / teaching assignment in Canada
- Reciprocal student exchange
- Duration 1.11.2017 – 31.10.2019



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Flax fabric uncoated (a), coated with diluted epoxy resin (b) and in curved state (c)

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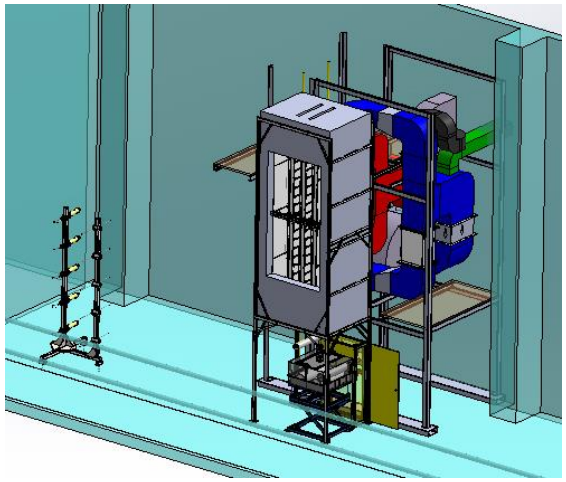
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Surface modification facility at technical scale
Wet-chemical treatment of yarns and textiles

- Continuous surface treatment of various textiles and (filament) yarns
  - up to 50 cm (width)
  - Speed: 15 m / min
- Liquids
  - Aqueous solutions
  - Organic solvents
  - High-viscosity pastes
  - etc.
- Operational start
  - November 2018
- Funding organization: Fraunhofer Gesellschaft



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Equipment for the surface modification of fibers and textiles (CAD)



Exemplary equipment for yarn modification

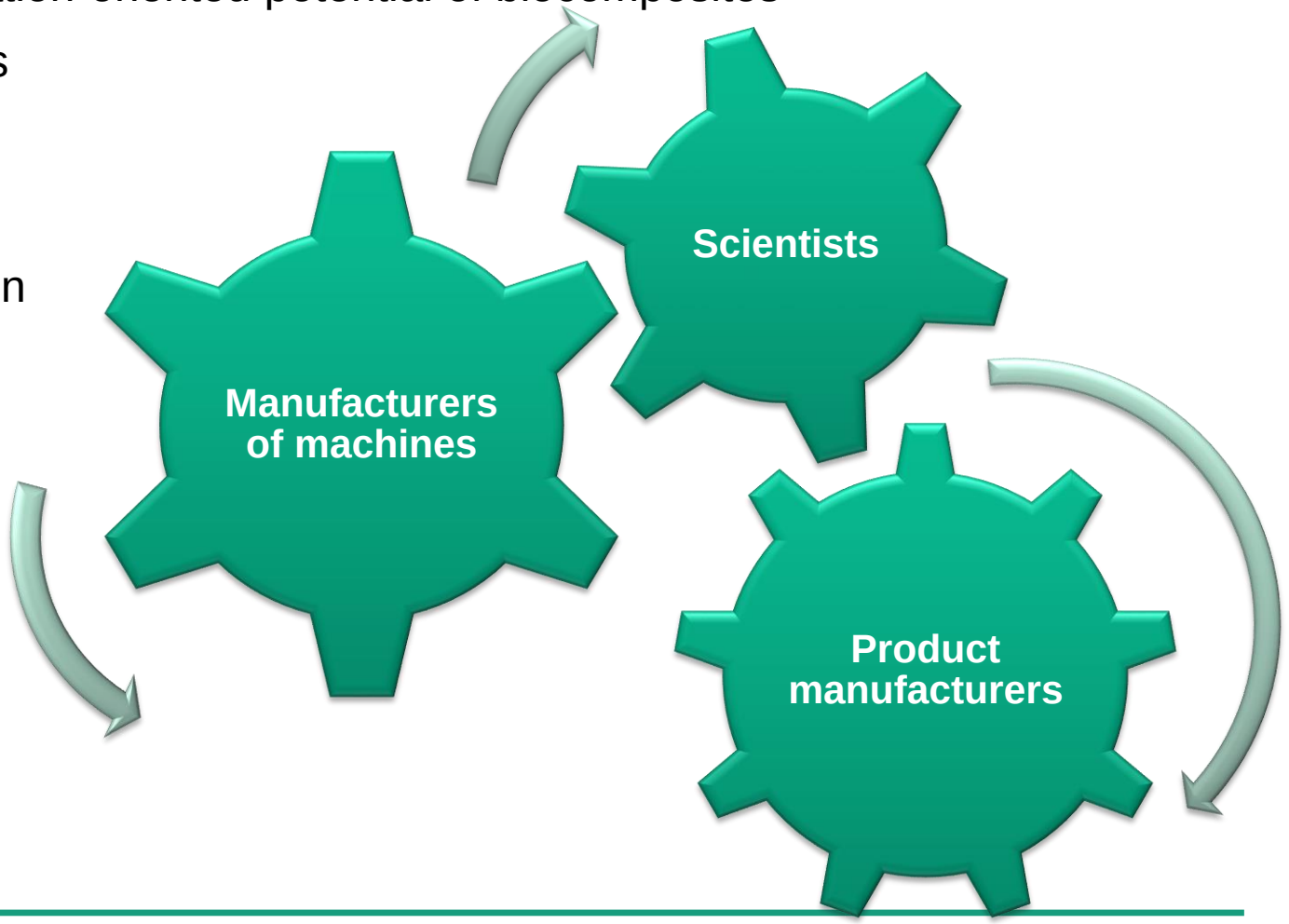
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Conclusion

- Implementation of the application-oriented potential of biocomposites
  - Novel technologies
  - Hybridization
  - Compatibility
  - Function-integration
  - Cost-effectiveness



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WKI Workshop in Canada

25.-26.10.2018 in London ON

- Competence exchange between scientists and industry
- Identification of new ideas and topics for collaborative projects
- Efficient use of renewable resources for industrial applications
  - Optimization of reinforcement fibers and fabrics
  - Manufacture of biocomposites
  - State-of-the-art manufacturing technologies
  - Properties of the biobased products
  - Analytics
  - Recycling / End of Life scenarios
  - Life Cycle Analysis



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Contact data

Fraunhofer Institute for Wood Research, Wilhelm-Klauditz-Institute WKI
Fraunhofer Application Center HOFZET
Heisterbergallee 10a, 30453 Hanover, Germany



Madina Shamsuyeva, M. Sc.
Research associate
Tel: +49 (0)511 9296 2291
Mail: madina.shamsuyeva@wki.fraunhofer.de

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