Leibniz Gemeinschaft

Leibniz-Institut für Verbundwerkstoffe

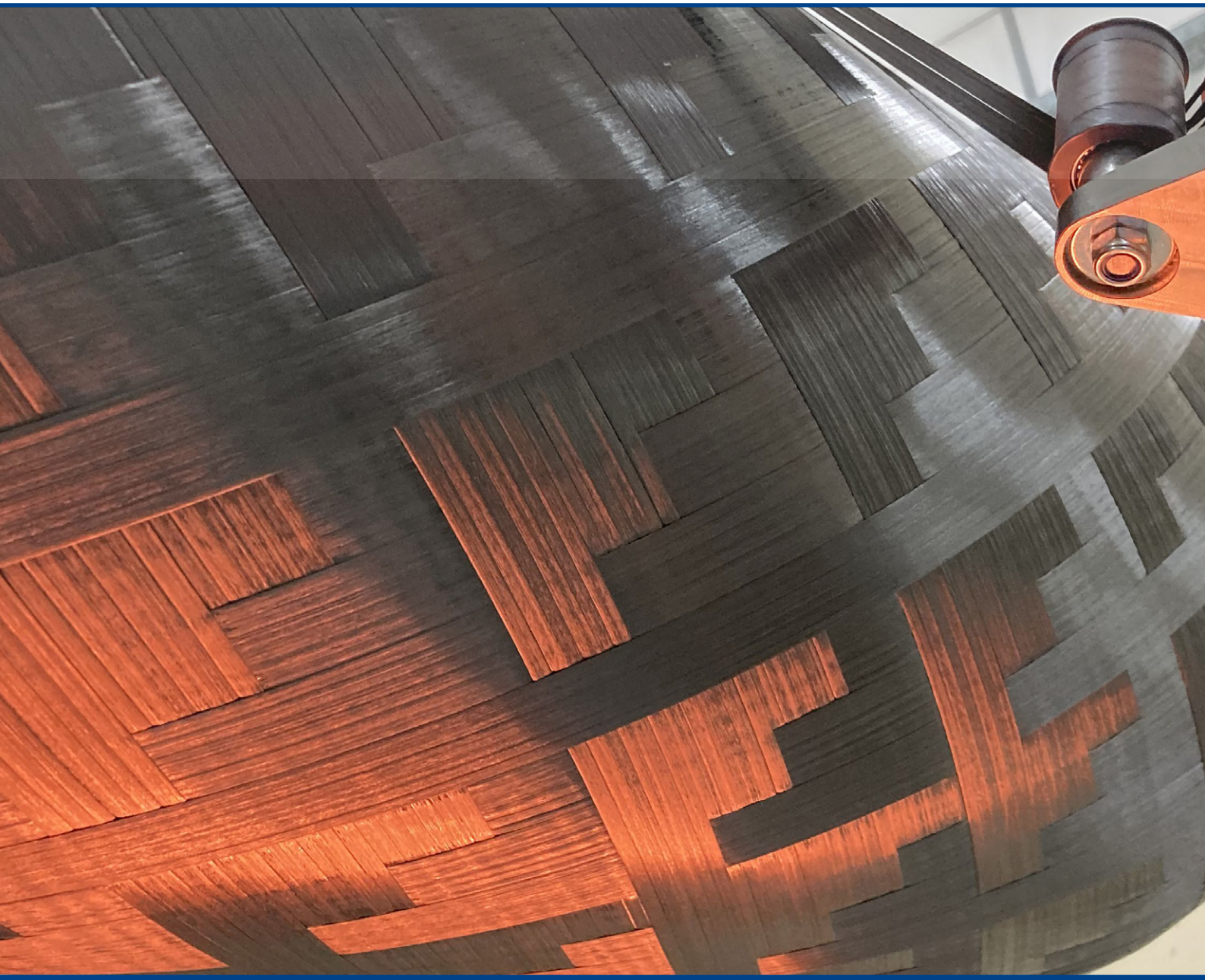

Photo Michael Päßler: TowPreg Winding of a 700bar Hydrogen Tank using IR Pre-Heater

Annual Report 2023

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Leibniz-Institut für Verbundwerkstoffe at a Glance

2023

Overall budget [m€]	**14.5**
Project funding [m€]	**5.9**
Investments [m€]	**1.7**
Projects	**140**
Publications in peer-reviewed journals	**26**
Lectures, laboratories	
· *Summer term [h]*	**18**
· *Winter term [h]*	**32**
Doctorates	**3**
Staff	
· *Permanent staff**	**64**
· *Scientific staff**	**51**
· *Guest scientists*	**10**
· *Student assistants*	**31**

** FTE*

As a member of the Leibniz Association, the institute receives institutional grants in accordance with the AV-WGL for the joint financial support of institutions by the federal and state governments (federal share 50%, share of the state of Rhineland-Palatinate and the entirety of the states 50%).

CONTENT

ANNEX

Dear Readers,
2023 got off to a great start for us with the award of a coveted prize for our latest spin-off project "isitec composites". The business idea, which prevailed against other top-class applications for the Leibniz Association prize worth 50,000 euros, is a novel manufacturing process that can be used to produce pipes for transporting hydrogen very efficiently. It is based on an impregnation technology developed at IVW. The founding team introduces itself on page 71.

Hydrogen was also a central topic of our work in the "WaVe" project, in which new pressure vessels in fiber composite construction were developed for a hydrogen-powered Unimog. We successfully passed the pressure test at 1600 bar (page 38). We are also looking into future storage options for liquid hydrogen. In a project funded by the state of Rhineland-Palatinate, we are researching the relationship between thermo-mechanical stress, microcracks, tight-ness and strength (page 32).

Just in time for Rose Monday 2023, six of our doctoral students proved that research can also be communicated in a very humorous way. At the "Science Slam" organized by CU e.V., the task was not only to present the respective topic in a way that was generally understandable, but also as entertaining as possible in a maximum of seven minutes. We have recorded the results for you at https://www.youtube.com/watch?v=503w-lrfah8.

Our international IVW colloquium took place again in September with over 20 scientific presentations of the latest work in the fields of Component Development, Materials Science, Manufacturing Science and Digitalization. This time, one session was dedicated to the retirement of Prof. Dr.-Ing. Mitschang, and we welcomed Prof. Dr.-Ing. Neumeyer, who has taken over as Research Director of Manufacturing Science at our institute. As in other areas, digitalization is becoming increasingly important in the field of fiber composites. Since the beginning of the year, we have created a new department at IVW for this purpose. With ever more advanced methods, we will succeed in significantly reducing the effort involved in the development and characterization of new fiber composites, their production and component properties, while at the same time improving our understanding (page 17). To this end, we are also a member of the renowned Leibniz Research Network "Mathematical Modeling and Simulation" and are already looking forward to hosting the "MMS Days 2024" at IVW in Kaiserslautern from April 10 to 12, 2024.

We are working on a completely new topic, vitrimers, in the DFG's Walter Benjamin Program. In the future, these materials could offer the possibility of combining the interesting advantages of thermoplastic fiber composites, such as meltability, formability and weldability, with those of thermoset systems, page 19.

The recruitment of young scientists is and remains one of our major concerns. This summer, we therefore made our fiber composites "tangible" in the truest sense of the word in the "MI(N)Tmachwelt" at the "Gartenschau" in Kaiserslautern for students from grades 8 to 13 with bicycles, frisbees and ball tracks. We also organized another competition for our students in 2023. Using a few given materials, including glass and carbon fiber fabric with synthetic resin, they had to design, calculate, build and test a means of transport that could transport a full can of Coke undamaged over a distance of 40 m in the shortest possible time. Fiber-reinforced tubular constructions working with positive and negative pressure, 3D-printed Chassis constructions made of polylactic acid plastics with an ingenious rubber traction system, designs working according to the gondola principle and a trebuchet (page 72) were used.

We would like to thank all our partners and customers for their excellent cooperation and wish you all a successful 2024.

Yours sincerely

Pascal Sadaune *Ulf Breuer*

From Fundamental Research to Application

The Leibniz-Institut für Verbundwerkstoffe (IVW) is a non-profit research institution of the state of Rhineland-Palatinate and University of Kaiserslautern-Landau (RPTU). It researches fundamentals for future applications of composite materials, which are of great importance for the mobility of the future, the fields of energy, climate and environment, production technology as well as for health care. New materials, construction methods and manufacturing processes are investigated and – after the basic understanding has been developed – tailor-made for the respective requirements. The focus is on the entire process chain, from basic materials to characterization and simulation, from construction methods and production technology to component testing and recycling. New ideas and innovative concepts are not only an essential part of the research and further development of the institute, but also lead to spin-offs. Newly acquired knowledge is transferred, above all into science, but also into teaching, the interested public and industrial applications.

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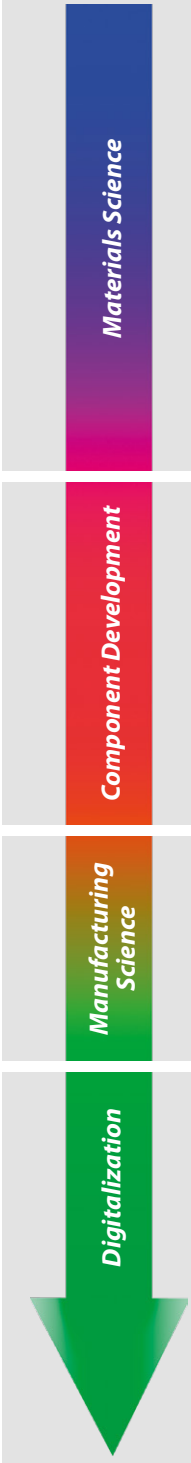
| Health | Mobility | Energy | Climate | Environment | Production Technology |
| Automotive | Aerospace | Mechanical Engineering | Medical Technology | Sports |

IVW Develops Composites for a Wide Variety of Applications

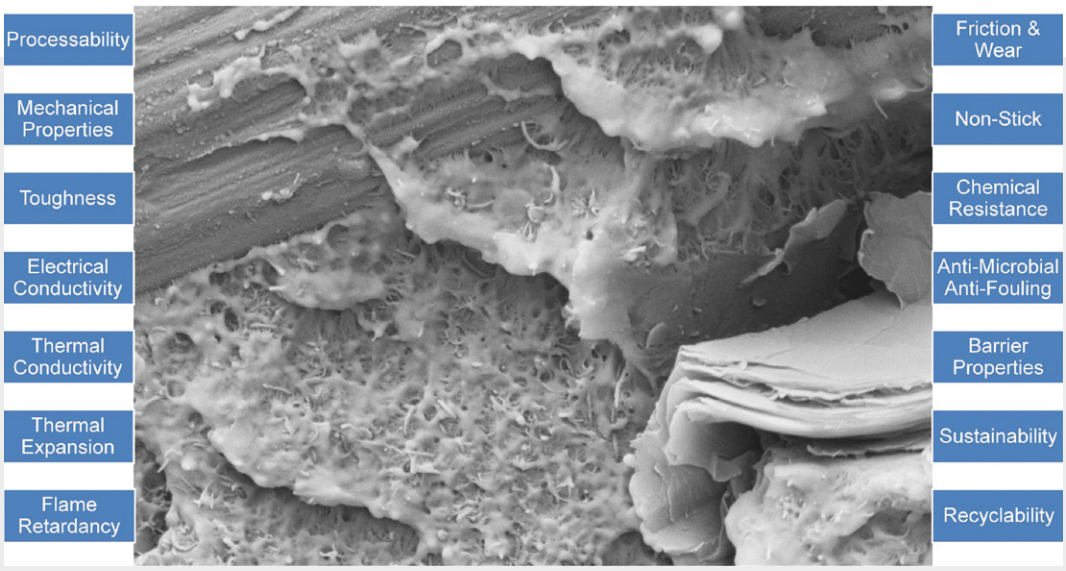
from A to Z

- *Component Control*
- *Component Testing*
- *Design*
- *Development of Semi-Finished Materials*
- *Failure Behavior*
- *Fatigue Analysis*
- *Filament Winding & Simulation*
- *Film Extrusion*
- *Forming Technology & Simulation*
- *Functionalized Matrix Systems*
- *Hybrid Materials & Structures*
- *Hybrid Processes*
- *Hydrogen Storage & Technologies*
- *Impact / Crash Behavior & Simulation*
- *Joining Technology / Welding & Simulation*
- *Material Analytics*
- *Methods of Material & Process Characterization*
- *Multi-Axial Material Testing*
- *Multifunctional Composites & Simulation*
- *Nanocomposites*
- *Non-Destructive Material / Component Testing & Simulation*
- *Press Molding Technology & Simulation*
- *Resin Injection Technology & Simulation*
- *Stress Analysis*
- *Tape and Fiber Placement & Simulation*
- *Textile Preform Technology*
- *Tribology*

FIELDS OF COMPETENCE
Overview



Tailored Thermosets & Biomaterials

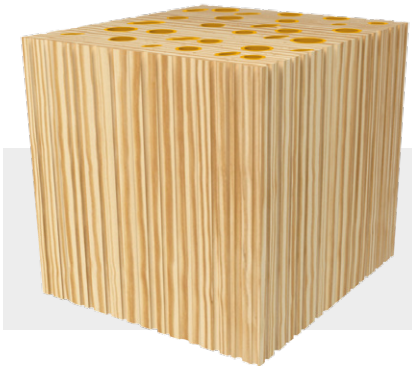


Multifunctional properties of polymer composites

The competence field develops high-performance multifunctional composites with thermoset matrix. As a bottom-up technology platform, an innovative "materials toolbox" is being developed and applied. New materials, preferably based on biogenic resources, and functional nano- and micro-reinforced materials as well as fibers are used to equip composites with tailored properties.

Particular attention is paid to their sustainability and durability, even in aggressive environments, as well as their (chemical) recyclability at the end of their life cycle. To this end, environmentally friendly, scalable manufacturing and recycling processes are being developed and liquid materials are being processed from laboratory scale to quantities of 200 kg on an industrial scale.

The aim is to develop material innovations based on a mechanistic understanding and correlation of processes, structures and properties. State-of-the-art analytical techniques from the spectrum of engineering, chemical and physical methods are used, such as fracture mechanics in media, atomic force microscopy with IR mapping and temperature-modulated optical refractometry.



Model structure of delignified wood

TYPICAL QUESTIONS

- *How can properties and processability of thermosets be improved without increase of costs?*
- *Which thermosets are resistant against strong alkaline media in order to reach high durability in applications?*
- *Which equivalent or better material can substitute a material no longer available on the market?*

SPECIAL EXPERTISE

- *Broad expertise in material selection, processing and characterization*
- *Development of thermoset composites with tailored and multifunctional properties*
- *Scalable processing technologies and methods according to industrial standards*
- *Further development of characterization methods*

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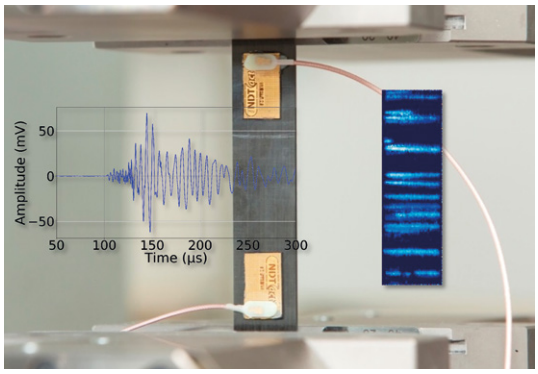
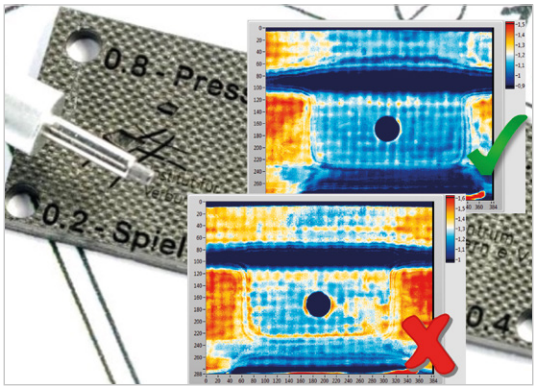
Tailored & Smart Composites

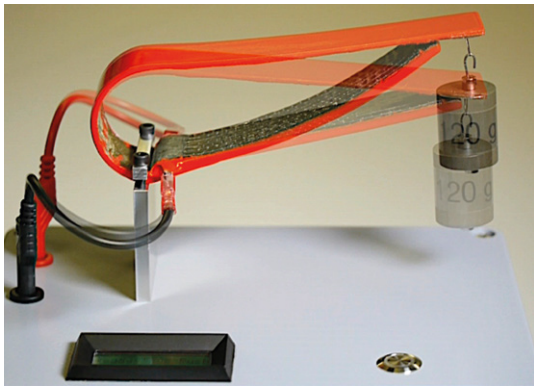
From multifunctional material to system – composite materials allow a variety of functional properties to be combined with optimal structural performance. This makes them a key element of mechatronics and adaptronics, a rapidly advancing field of research today. The main challenge is to master the complex property profile of these materials along the entire development chain from design and production to system integration and testing of the finished component. This is where the research activities of the competence field Tailored & Smart Composites start: The focus is on understanding the relationships between structure, process, and the resulting properties of multifunctional composites. We are working on the development of new methods for non-destructive testing of composite materials and we integrate sensors or actuators in fiber-reinforced components so that they can adaptively adjust to their environment. After their design by finite element methods, we can produce such materials using standard methods, process them into components or semi-finished products and comprehensively characterize both the material properties and the special functions.



TYPICAL MATERIALS

- *Composites*
- *Piezo ceramics*
- *Shape memory alloys*





TYPICAL QUESTIONS

and challenges on the way from material to system are...

- *the effcient theoretical and experimental description of the complex property profiles of multifunctional materials*
- *the development of suitable measuring and testing equipment and associated methods for multiphysical material characterization*
- *the development of complexity-adapted, cross-scale material models for processing and component design*

SPECIAL EXPERTISE

- *"One Stop Shop": design – simulation – realization – testing*
- *Combination of composite know-how with smart materials expertise*
- *Hybrid composites based on various material combinations*

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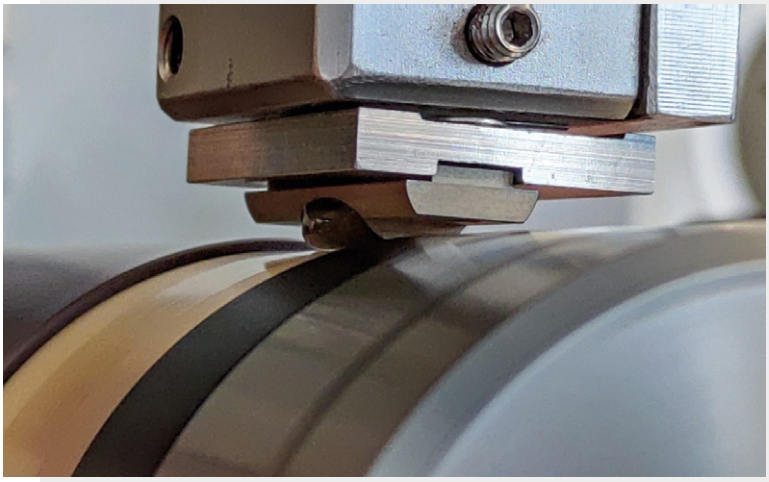
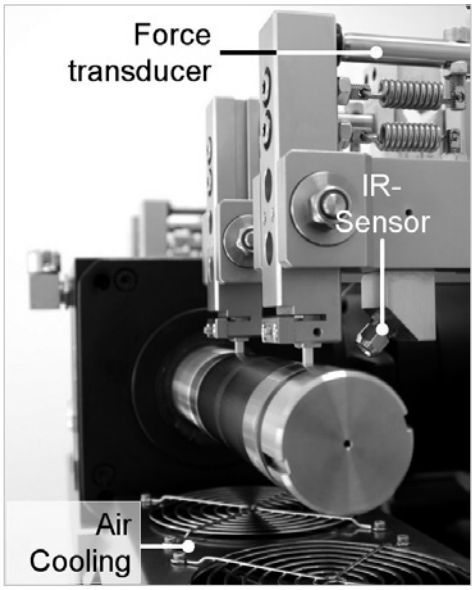
Tribology

In the field of Tribology, our specialty lies in the development of innovative composite materials that possess outstanding thermal stability and low friction coefficients. These properties allow for prolonged service life even in the most demanding applications. Our approach involves a comprehensive analysis of the specific technical requirements or research questions, coupled with our extensive expertise gained from fundamental scientific research.

When creating new materials, we employ custom-designed tribometers fitted with high-precision sensors and employ pioneering testing procedures. These tools and methods help us gain a deep understanding of the intricate interaction between friction and wear, as well as the relationships between material composition, material processing, material microstructure, and tribological properties.



Oil film on a polymeric ring during a gear substitute test



Block-on-Ring Tribometer

TYPICAL MATERIALS

- *Thermosets, thermoplastics, elastomers*
- *Glass/carbon/aramid fibers*
- *Micro and nanoparticles, solid lubricants*

TYPICAL QUESTIONS

- *How does the material composition influence the stability of transfer films?*
- *How can tribological model tests be designed so that they can replace plain bearing tests?*
- *How must laboratory information systems be designed so that they best represent tribological material tests?*

SPECIAL EXPERTISE

- *Application-oriented customized development of composite materials and manufacturing processes, tribological testing procedures and methodology, component testing*

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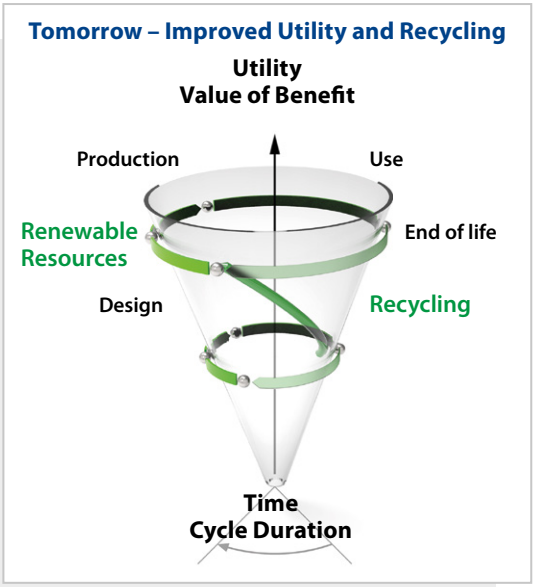
Material Cycles

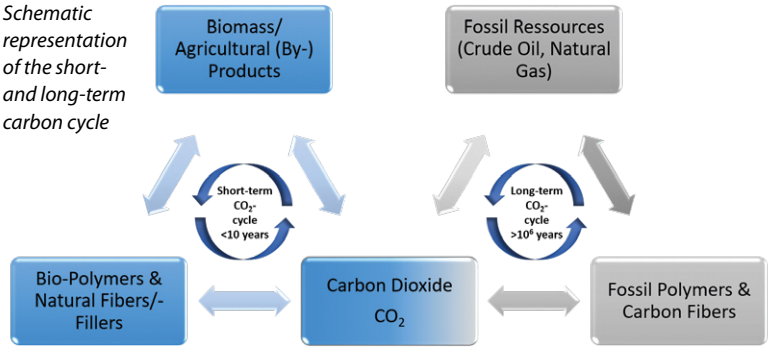


Schematic representation of improved utilization and recycling to prolong the duration and value of materials' applications

This research group focuses on fundamental issues related to the use of materials in a closed carbon cycle. Particular attention is paid to the use of renewable raw materials, such as natural fibers or biopolymers from renewable sources. The second focus is on the recycling of materials and components made of composites, and especially those with carbon fibers, since it is another important aspect in the optimal use of raw materials.

Across topics, thermal resistance and surface properties for best possible fiber-matrix bonding and high-performance use are key issues. Naturally occurring structures in natural fibers can, if used in a targeted manner, add value through additional functionality. Understanding this fundamentally is also the subject of research in this competence field.

Schematic representation of the short- and long-term carbon cycle



TYPICAL MATERIALS

- *Polymers, fibers and additives from renewable resources*
- *Recycled fibers and polymers*
- *Materials from their end-of-life phase*

SPECIAL EXPERTISE

- *Modern testing facilities with coupling options for material properties such as:*
  - *Thermal degradation in controlled environments*
  - *Melting and crystallization behavior as well as curing behavior of polymers*
  - *Thermal expansion and shrinkage*
  - *High resolution structural analysis incl. determination of fiber orientation and void content*
  - *Damage analysis and investigation of impuritie*
  - *Surface energy analysis and wetting behavior*

TYPICAL QUESTIONS

- *How can materials from end-of-life components be brought into new high-performance applications with consistent quality?*
- *How can sustainable materials be used and add value to composite applications?*
- *How do properties of natural fibers influence the behavior of composite materials?*

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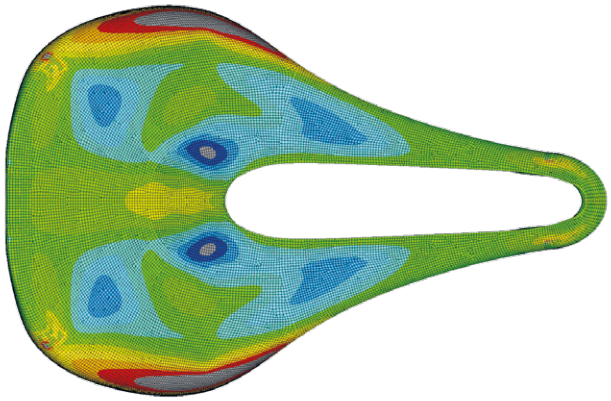
Design of Composite Structures

The area Design of Composite Structures covers the development of optimized lightweight structures of fiber reinforced polymer composites (FRPC) for new applications as well as the substitution of existing designs made of other materials. Finite element program systems (e.g. ABAQUS, ANSYS) with specialized meshing and CAD programs (ANSA, SolidWorks), optimization tools (e.g. TOSCA, Isight) and in-house developed subroutines for modeling, fiber alignment optimization and description of strength and failure mechanisms of FRPC (strength criteria, degradation, non-linear material models, unit cell modeling) are applied.



TYPICAL APPLICATIONS (examples)

- *Fuselage and tail structures, high lift components*
- *Body-in-white and undercarriage structures*
- *Highly accelerated machine parts*
- *Bicycle frames and -parts*
- *X-ray transparent implants, orthosis*
- *Pressure vessels, hydrogen storage systems, rotor shafts*

SPECIAL EXPERTISE

- *Lightweight pressure vessel design for optimal use of installation space*
- *Development of complex, integral FRP-structures*
- *FEA unit cell model for prediction of stiffness and strength of 3D-reinforced laminates*
- *Algorithm for fiber angle determination from CT-measurement*
- *Mapping of fiber orientation from CT measurement or material simulation to FE model*
- *Expertise concerning load application in thick-walled FRP-components*
- *Combination of fiber angle- and topology optimization*
- *Validation of structural design and analysis by experimental testing*
- *Topology optimization*

TYPICAL QUESTIONS

- *Can structural components with good mechanical properties be produced by using recycled fibers?*
- *Is a high level of lightweight design quality achievable even for complex component geometries by cleverly combining continuous fiber-reinforced and short fiber-reinforced areas?*
- *How can lightweight FRP hydrogen tanks and pipelines be designed for a safe operation?*

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Mechanical Characterization & Modeling

This field of competence covers the experimental and simulative analysis of materials, structures and joints, especially influenced by strain rate and temperature. Key aspects are the evaluation of material properties (parameters, stress-strain-curves,…) and the transfer of this behavior into validated material models for FE-simulation. Within these activities, testing procedures are newly developed or optimized. The improvement of energy absorption and structural integrity in tension and bending loaded composite structures and joints is an additional focus in this competence field.

SPECIAL EXPERTISE

- *Mechanical characterization of materials using modern high performance measurement equipment*
- *Validation of FE-models for composites*
- *FE-modeling by ABAQUS and LS-Dyna*
- *Modern testing equipment and technologies:*
  - *2 high speed tension machines: material characterization up to 160 kN testing force at velocities of 0.1 mm/s to 20 m/s and temperatures from –100°C to 250°C*
  - *Crash rig up to 22 kJ impact energy for testing of substructures*
  - *Drop tower for impact tests up to 3 kJ impact energy*
  - *Local optical deformation measurement (DIC) for evaluating of material properties and validating of simulations*
  - *3D-ultra-high-speed pictures up to 1 million Hz frames per second*
  - *3D-ultra-high-resolution pictures up to 40 MPix*

TYPICAL MATERIALS

- *CFRP, GFRP, AFRP*
- *Continuous and discontinuous fiber reinforcement*
- *Hybrid materials*

TYPICAL QUESTIONS

- *Will you support us in creating FE-parameter sets for FE-simulations or with validating simulation results?*
- *Are you able to test materials and structures also under the influence of temperature and varying test velocities?*
- *How can structures made of FRP absorb energy effectively and show a good structural integrity even under tension?*

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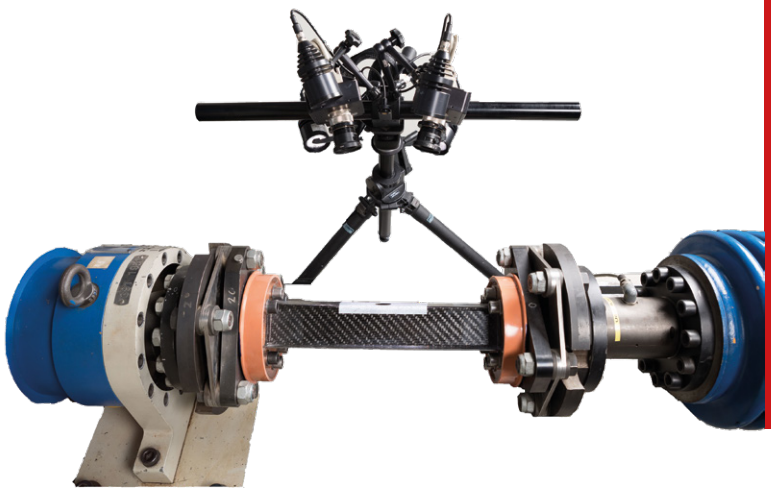
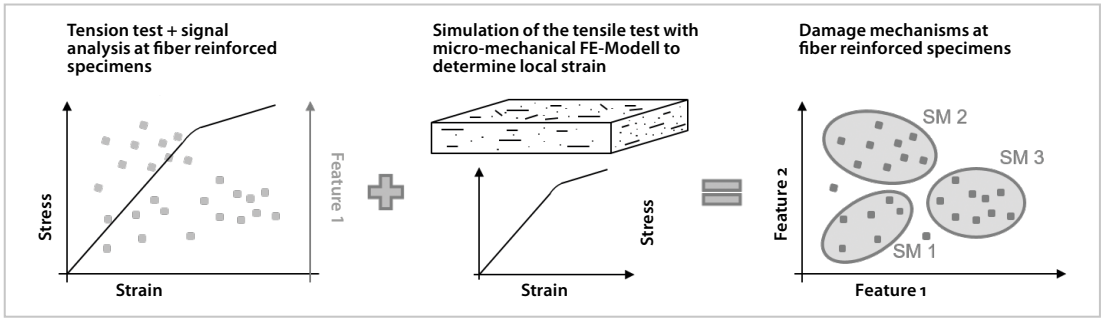
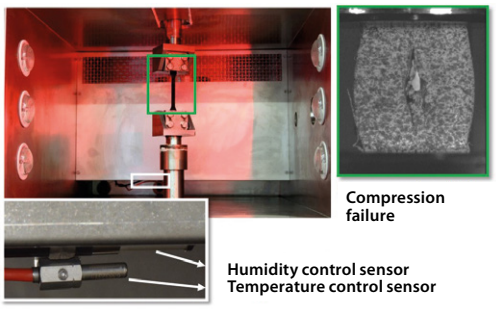
Fatigue & Life Time Prediction



In the competence field Fatigue & Life Time Prediction research is being carried out on experimental characterization and modeling of the fatigue behavior of fiber reinforced polymers, the identification of input parameters for the fatigue life analysis (fatigue strength, decrease of residual strength, stiffness degradation), and the detection of damage mechanisms i.e. of short fiber reinforced thermoplastics and their influence on life time. The development of sophisticated testing methods and data analysis is used for reliable lifetime prediction with least testing effort. A further topic is the experimental fatigue life testing under environmental conditions.





TYPICAL MATERIALS

- *GFRP*
- *CFRP*
- *Continuously and discontinuously reinforced polymer composites*
- *Thermoplastic and thermoset matrix systems*

TYPICAL QUESTIONS

- *Are micro damages detectable which determine the life time behavior?*
- *How are fiber and matrix material influencing the fatigue properties?*
- *What is the effect of temperature and humidity on the fatigue behavior of fiber reinforced polymers?*

SPECIAL EXPERTISE

- *Fatigue life simulation*
- *Multiple test facilities and measurement methods*
- *Component test rig with 6 channel control*
- *Cyclic testing in climate chamber and at high and low temperatures*
- *Uni- and multi-axial materials characterization*
- *High frequency test rig*
- *3D optical strain and deformation measurement*
- *Linking to structural FEA*
- *Acoustic emission and thermography measurement equipment*

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Press & Joining Technologies

This field of competence focuses on the development of new, eco-efficient materials and processes for thermoset sheet molding compounds and thermoplastic organo sheets. A particular focus is placed on processes for the closed-loop and cascade use of FRPCs, whereby technologies for processing staple fiber yarns with standard or modified thermo-plastics are being investigated. A key area in compression molding of SMC, LFT and GMT is the use of renewable or recycled raw materials and process development for composites using conventional or bio-based polymers and fibers. Minimizing the use of energy and resources is a central aspect of the activities pursued in this field. Another focus is on the development of efficient joining technologies for thermo-plastic FRPC and metal-FRPC hybrid materials. Finally, combinations of the technologies mentioned here to form new processes and production chains are also under investigation

TYPICAL QUESTIONS

- *Is it possible to predict the properties of composites made from renewable raw materials?*
- *How can composites contribute to electro mobility?*
- *Can vitrimers replace thermoplastics?*

SPECIAL EXPERTISE

- *Combination of continuous / discontinuous fiber reinforcement*
- *Development of special profile shapes – open and closed – in continuous compression molding (CCM) technology*
- *Biocomposites*
- *Industrial scale equipment:*
  - *SMC production line*
  - *Continuous compression molding press*
  - *Several parallel controlled presses with up to 2,500 t press force and mounting table size of up to 2 m x 3 m, IR field and integrated injection molding unit for hybrid thermoforming and compression overmolding*
  - *Welding robot*
  - *Different test rigs for induction welding*
- *Foam core materials for thermoplastic sandwich structures*
- *In-line and off-line process monitoring*
- *Digital mapping of process chains*

TYPICAL MATERIALS

- *Fiber reinforcement GF, CF, rCF, NF, AF in form of textiles or cut fibers*
- *Combinations of continuously and discontinuously reinforced systems*
- *PP, PA, PPS, PEI, PEEK, PU, EP, UP, biopolymers, vitrimers, etc.*

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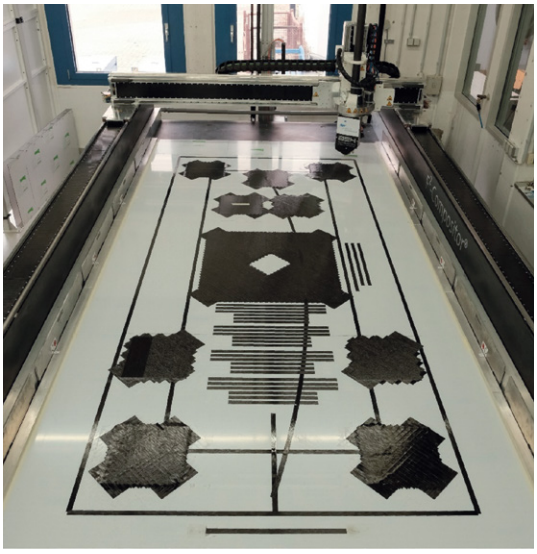
Roving & Tape Processing

Research goal is the development of more efficient manufacturing processes by filament winding, tape laying and 3D-printing with continuous fiber-reinforced thermosetting and thermoplastic matrices as well as hybrid injection molding including process specific tooling and novel manufacturing equipment solutions. Research focuses on quality management, process control, process optimization and process automation such as in-line direct impregnation, ring winding technology, "out-of-autoclave" process by in-situ consolidation or the extension of additive manufacturing technologies (3D printing) and injection molding technology with continuous filaments in load direction.



Tie-bar-less injection molding machine with automation cell

TYPICAL MATERIALS

- *GFRP, CFRP, rovings, tapes (virgin and recycled), prepregs, epoxy resin, polyester resin, PP, PA, PPS, PEI, PEEK, etc..*

TYPICAL QUESTIONS

- *How can the filament winding process be upgraded for large-scale production?*
- *How can the quality of unidirectionally reinforced thermoplastic semi-finished products be determined?*
- *In which areas can hybrid injection molding be used particularly economically?*

Ultra-fast multiaxial tape laying machine

SPECIAL EXPERTISE

- *Industrial scale equipment:*
  - *Ultra high speed tape laying gantry system (3.5m x 1.5m layup area, up to 4 m/s layup speed)*
  - *Industrial robot with tape laying head (Innovation Award) and external rotation axis (robot winding)*
  - *7-axis winding machine for conventional wet winding, thermoplastic winding and towpreg winding*
  - *Ring winding head with 48 rovings for increased throughput (JEC Innovation Award)*
  - *Siphon impregnation technology*
  - *Tie-bar-less injection molding machine with automation cell*
- *Development of procedures specifically for large quantities*
- *Special tape-laying developments (TP tapes, TS tapes, binder tapes, towpregs)*
- *Autoclave with inert gas environment (up to30bar)*
- *3D-printers also with endless fiber reinforcement*

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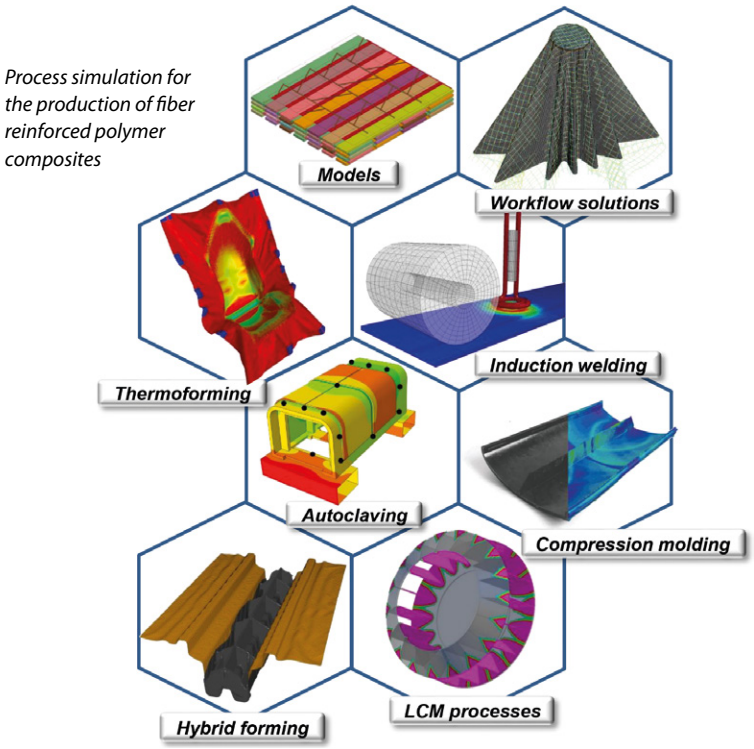
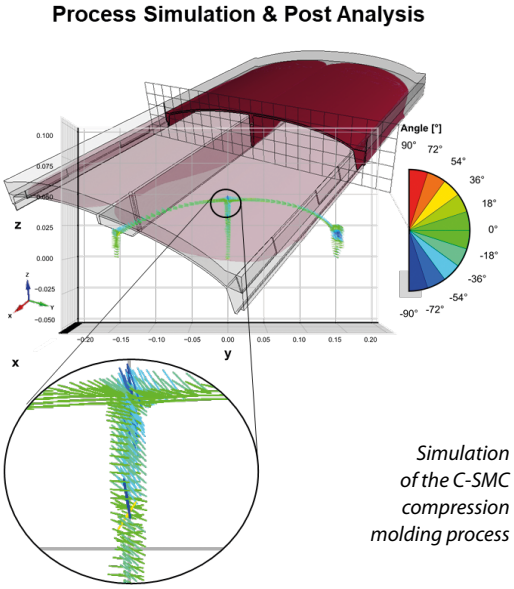
Process Simulation

Process modelling and simulation is the cornerstone of Digitalization and Industry 4.0. In this competence field the focus lies on the development of simulation methods, CAE-workflows and material models for the systematic optimization of all manufacturing processes used to create fiber reinforced polymer composite parts.

Application-specific implementation of simulation tools based on commercial and/or open source CAE software are used to carry out systematic studies for optimizing process parameters, tools, component design, sensor positioning and semi-finished product selection. Furthermore, software tools are developed for data transfer within consistent simulation chains, e.g. transfer of process simulation results into mechanical component simulations. Finally, the validation of individual material models based on self-developed experimental and Process simulation for the production of fiber reinforced polymer composites



Process simulation for the production of fiber reinforced polymer composites



Simulation of the C-SMC compression molding process

CURRENT RESEARCH TOPICS

- *Faster process simulations through model order reduction and machine learning*
- *Thermoforming simulation for customized preforms made from unidirectional reinforced materials*
- *Material models for C-SMC with very high fiber volume fraction*

TYPICAL QUESTIONS

- *How do different semi-finished products behave during the pressing process?*
- *How can fiber orientations and wrinkling be predicted during thermoforming of organic sheets?*
- *How can the filling time in LCM processes be optimized by adapting gating scenarios?*

SPECIAL EXPERTISE

- *Latest commercial and open source software packages*
- *Automatable scripts for data transfer and parameter studies*
- *Modular shell and beam element material model for accurate prediction of fiber orientation*
- *Material model for C-SMC materials*

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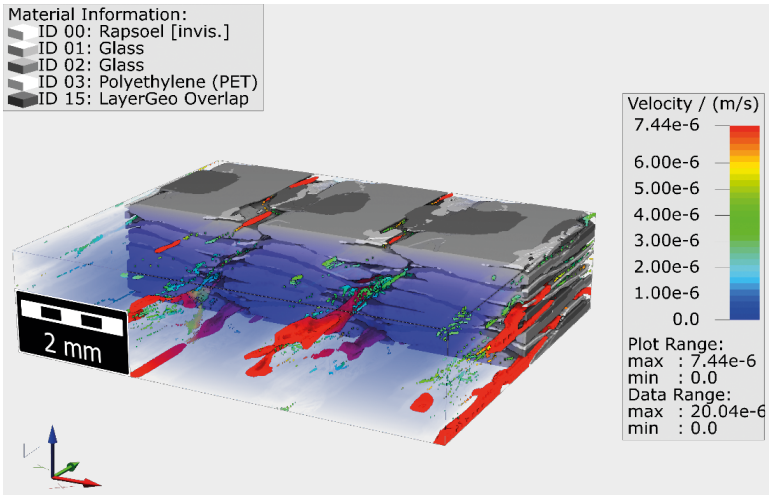
Digitalized Process & Material Development

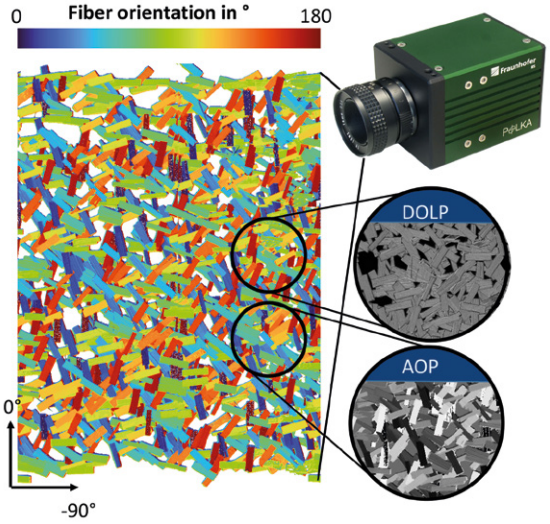
Digitalization forms the basis for efficient product development. Our focus is on the corresponding hardware and software based digitalization "tools" themselves.

Following the principle of "the right sensor at the right place", application-specific concepts for data acquisition are developed and realized, whereas virtual studies with process simulation models make it possible to minimize data acquisition effort and to maximize information value at the same time. This research area includes micro-scale material simulation for predictions of material behavior during processing and application. To build up the necessary material understanding, validate models and generate input data, innovative experimental methods for characterizing the processing behavior of semi-finished products are developed. In all areas, machine learning methods are applied for effective data analysis.

All technologies are developed for the entire spectrum of composite process chains and materials. A special focus, however, is on liquid composite molding (LCM) processes.



Flow simulation throught a textile model



Machine Vision based on polarization imaging

TYPICAL QUESTIONS FROM INDUSTRY

- *Which sensor types and positions provide the most meaningful process data?*
- *How can machine learning methods be used for quality assurance?*
- *Which liquid impregnation process is suitable for my application?*

SPECIAL EXPERTISE

- *Patented measuring systems, e.g. for textile permeability and organo sheet shearing*
- *Software packages for material simulation*
- *LCM-one-stop-shop: Tool design, material selection, manufacturing, testing*
- *Caprolactam-based Thermoplastic Resin T ransfer Molding*

CURRENT RESEARCH TOPICS

- *Workflows for computer generation of realistic textile models*
- *Machine vision based on polarization imaging for fiber recognition*
- *AI-based quality assurance for thermoplastic profile production*
- *RT storage-stable thermoset prepregs based on solid resins*

PD Dr.-Ing. habil. David May
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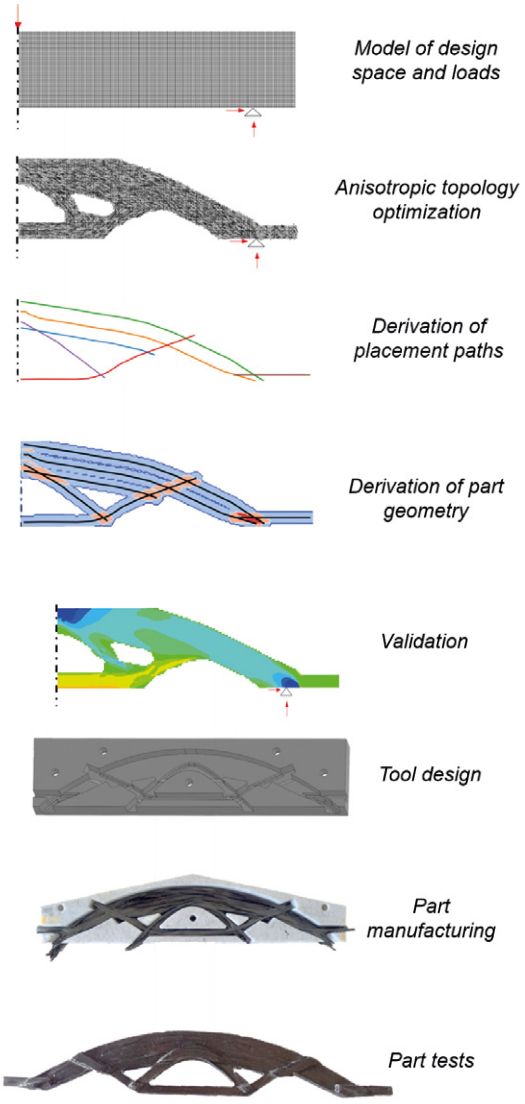
TopComposite – Topology-Optimized and Ressource-Efficient Composites

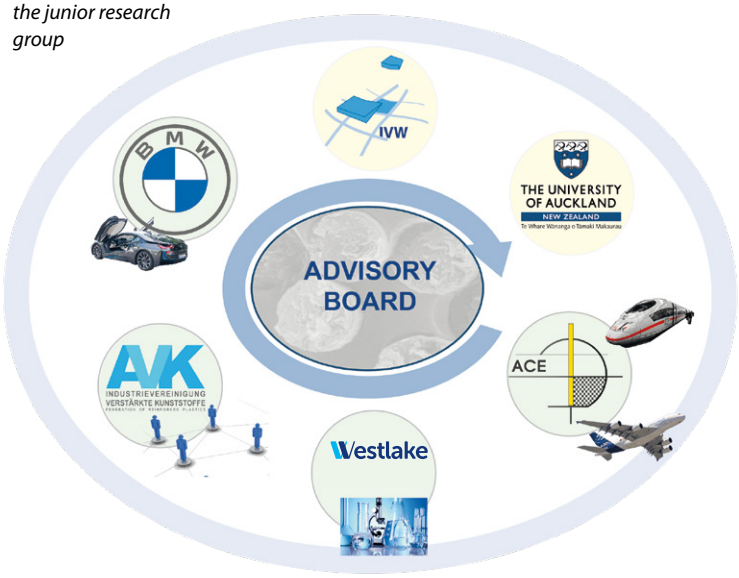
David May

In 2023, the interdisciplinary research group successfully accomplished the critical milestone evaluation and was rewarded with an additional two years of funding. It was therefore able to continue the research on the wet fiber placement, a novel additive manufacturing process for continuous fiber-reinforced thermosets. Among the highlights of last year's research is a dual-curing epoxy resin system. Based on two different curing reactions, it allows for long-term room temperature stability of the placed preforms as well as custom-tailored viscosity at different stages of the process. Furthermore, the automated placement system was fitted with a machine learning enhanced camera, that allows in situ monitoring of the fiber bundle positioning. Finally, a procedure was developed for multiaxial, anisotropic topology optimization.



Workflow for topology-optimization and placement path derivation

Advisory board of the junior research group



The group is funded by the German Federal Ministry of Education and Research (BMBF) for a period of five years after David May prevailed in the "NanoMatFutur" competition for young scientists. An academic-industrial advisory board supports the group.

SPONSORED BY THE
Federal Ministry of Education and Research

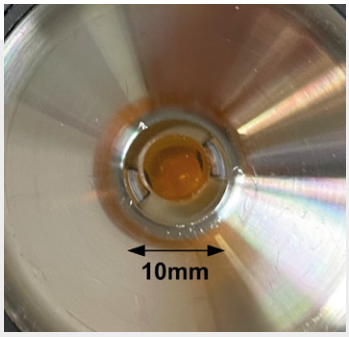
The junior research group "TopComposite – Topology-optimized and resource-efficient composites for mobility and transport" is funded by the federal ministry for research and education (funding reference 03XP0259).

Malleability of Cross-Linked Polymers – Vitrimers: A New Class of Polymer Matrices

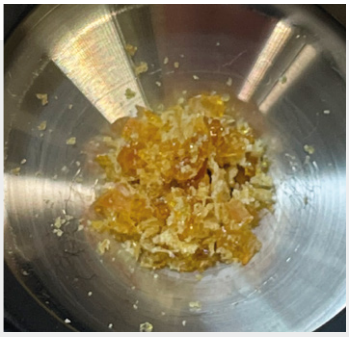
Andreas Klingler

Within the framework of a DFG-funded Walter Benjamin fellowship, this project focuses on the investigation of a new class of polymers called vitrimers. These materials combine the malleable character of thermoplastics with the extraordinary mechanical performances of highly cross-linked thermosets. This combination of properties is possible due to the presence of special, switchable molecular bonds in a cross-linked network structure. Depending on the temperature, vitrimers transit from the amorphous glass state via the glass transition to the viscoelastic solid state. In the special case of vitrimers, a third, viscoelastic liquid state is then reached with a further increase in temperature, in which an extensive exchange of molecular bonds takes place. This functionality allows the vitrimer to be repaired, reshaped or even recycled, even though the overall structural integrity of the material is retained. Hence, vitrimers represent not only a new type of sustainable polymer solutions, but also enable new future perspectives in processing technologies, e.g. through repeated forming processes, as well as opportunities to enhance the lifetime and durability of polymer applications in service. However, fully exploiting the special vitrimer properties currently lacks a better understanding of the underlying physical and physico-chemical mechanisms. This is especially important in the case of vitrimer-based composite materials, where additional physical and chemical interactions come into play, e.g. between fibers and a vitrimer matrix.

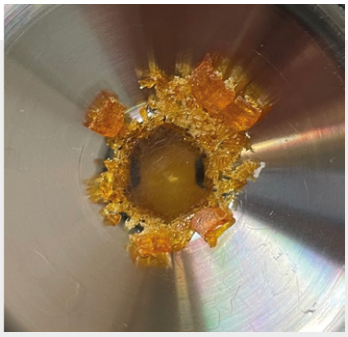
Therefore, the main objective of the two-year project is to gain a better understanding of the basic property mechanisms of vitrimers in order to further pave their way as sustainable polymer and polymer composite solutions.



Polymer network with shear stiffness



Destroyed sample



After temperature and force treatment

Vitrimer in its pristine state (left), after mechanical treatment (center) and after local healing (right)

For further details on the Walter Benjamin position and the project

The project "Malleability of highly cross-linked polymers – an investigation of the topology freezing phenomenon of vitrimers via static and dynamic means and its relevance for the solution of technological challenges" is funded by the German Research Foundation (DFG), project number: 521902629.

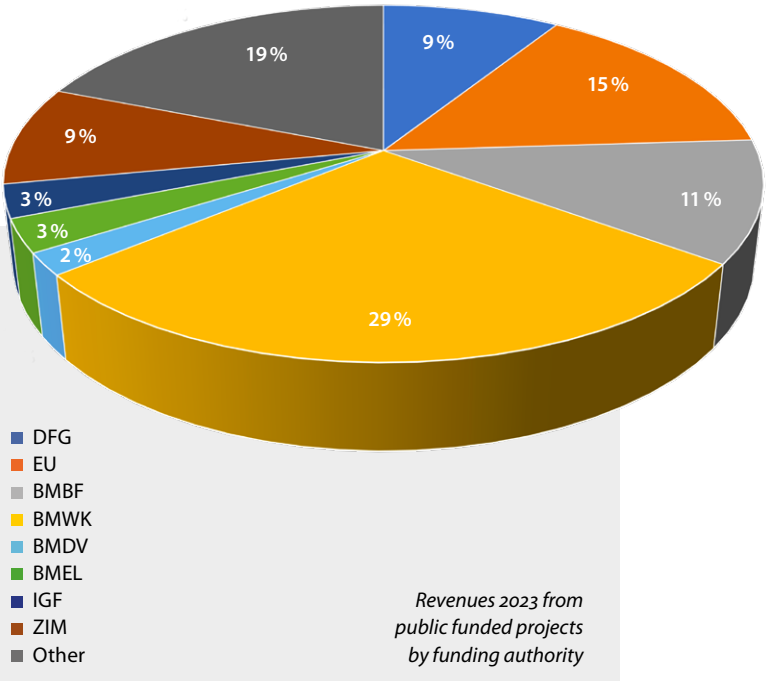
PROJECTS

In 2023, a total of 140 projects were processed. 53 projects were funded by public funding agencies such as

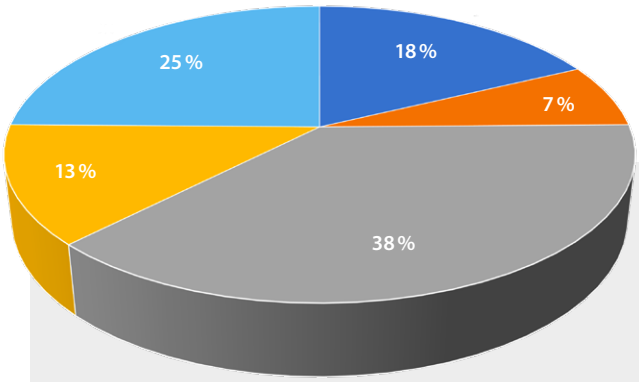
- the German Research Foundation (DFG)
- the European Union (EU)
- the Federal Ministry of Education and Research (BMBF)
- the Federal Ministry for Economic Affairs and Climate Action (BMWK)
- the Federal Ministry of Digital and Transport (BMDV)
- the Federal Ministry of Food and Agriculture (BMEL)
- the Industrial Cooperative Research (IGF)
- the Central Innovation Programme for SMEs (ZIM)

and others.

87 of these projects were bilateral research projects with industrial partners, with the greatest demand from the mobility sector, followed by the energy, climate and environment segment.



Revenues 2023 from public funded projects by funding authority



Industrial revenue 2023 by sector

Bio-Based Non-Isocyante and Phosgene-Free Polyurethanes

Against the background of sustainable chemistry and new regulations, research and industry are challenged to replace hazardous chemicals and harsh reaction conditions with more environmentally friendly intermediates and processes. In recent years, interest in polyurethanes (PU) has increased in the plastics market. These special high-performance polymers combine numerous properties needed in aerospace, medical, construction and automotive applications such as adhesives and textiles.

Classically, PUs are produced by polyaddition of a diol (or polyol) to a diisocyanate (or polyisocyanate). The latter is based on the highly toxic phosgene. PU chemistry is hazardous and sensitive to moisture. An excellent alternative is the development of non-isocyanate polyurethanes (NIPU), which are formed by polyaddition of a diamine (or polyamine) to a dicyclocarbonate (or polycyclocarbonate) and are phosgene-free.

IVW is developing biobased NIPU/epoxy hybrid foams under a grant from the Volkswagen Foundation. Oligomeric polycyclocarbonates from epoxidized vegetable oil have been investigated in polyaddition reactions with various biobased polyamines for the synthesis of NIPUs. Since this type of reaction does not lead to gas formation, a chemical blowing agent was also used for foaming. Hybridization of the NIPUs with epoxy resin improves the thermal and mechanical properties. The biogenic NIPUs use raw materials from Europe and avoid toxic phosgenation in the production of polyurethane products. Future products made from NIPUs can be manufactured with "green chemistry," resource-efficient production and within a circular economy, meeting the requirements of the construction and automotive industries.

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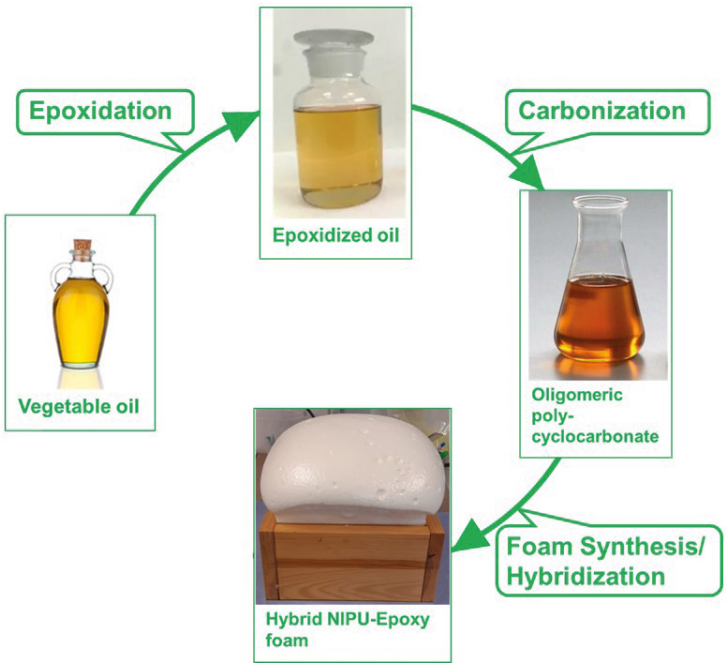

Manufacturing of NIPU/Epoxy hybrid foams

We would like to thank the Volkswagen Foundation (Funding for Refugee Scholars and Scientists from Ukraine, AZ9C048) for the support.

Nanoscale Structure and Property Imaging by Cutting Edge AFM Techniques

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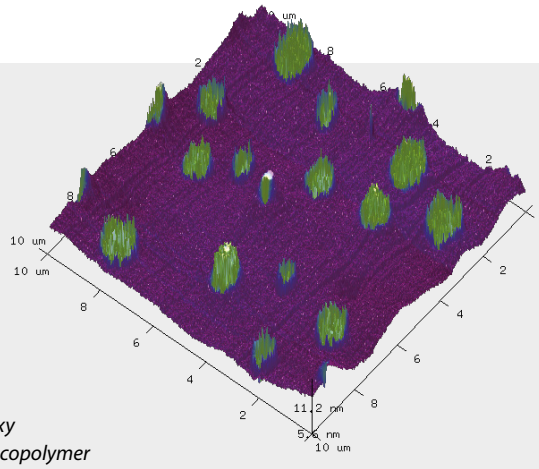
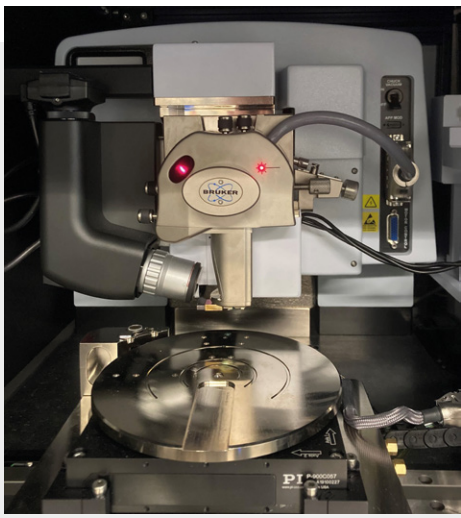
Atomic force microscopy is a technique that has been used for over 30 years to characterize the surfaces of various solids. It is a scanning probe microscopy technique, in which the interaction of a very fine tip (tip radius down to 10 nm) and the surface of the sample to be examined is determined pixel by pixel. The tip sits at the end of a cantilever, which is deflected by attractive or repulsive interactions between the tip and the sample. This produces an image of the topography, with the resolution essentially determined by the tip's radius of curvature.



Morphology of an epoxy filled with 5 wt% block copolymer green: high absorption of the C = C stretching vibration at 1640 cm⁻¹ characteristic for the block copolymer



AFM scanner and sample stage for the examination of specimens with diameters of up to 15 cm

With the AFM "Dimension IconIR" from Bruker, procured within the project "EFRE – REACT TPC-H2-Storage", it is now not only possible to image the topography of surfaces. In addition, by implementing novel AFM measurement modes, the following local material properties can also be mapped:

- Peak Force QNM: characterization of nanomechanical properties (deformation, DMT modulus, pull-off force, dissipation)
- Nano-DMA: nanoscale characterization of viscoelastic properties (storage modulus, loss modulus, loss factor)
- AFM-IR: nanoscale resolution IR spectroscopy in the 1800–800 cm^{-1} wavenumber range.
- Nano-TA: nanoscale thermal analysis in the range of RT – 350 °C

With the AFM, it is now possible to study and correlate the morphology of composite materials and their properties on a microscopic scale at the same location on the sample. This makes it possible to draw correlations to macroscopic material properties and gain a comprehensive understanding of them. The information obtained will provide new approaches for the development of composites with (multi-)functional properties and their manufacturing processes.

Das Projekt zum Auf- und Ausbau von technologieorientierten Kompetenzfeldern

TPC-H2-Storage

wurde als Teil der Reaktion auf die COVID-19-Pandemie von der Europäischen Union aus dem Europäischen Fonds für regionale Entwicklung gefördert.

The project "TPC-H2-Storage – Infrastructure Development for Thermoplastic Fiber Composite Pressure Vessels for Hydrogen Storage and Transport" was funded by the European Regional Development Fund (ERDF) as part of the Union's response to the COVID-19 pandemic.

Partner RPTU Rheinland-Pfälzische Technische Universität Kaiserslautern Landau · Johannes Gutenberg Universität Mainz · Max-Planck-Institut für Polymerforschung

Halocycles – Sustainable Cycles for PFAS Enabled by Electrochemistry

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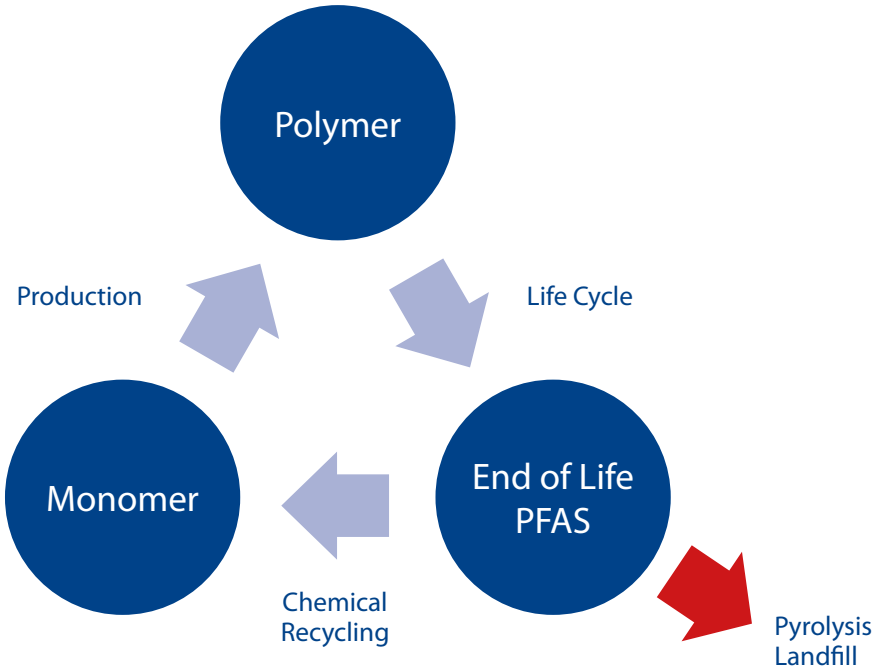
Per- and polyfluoroalkyl substances (PFAS) are synthetically produced industrial chemicals that exist in a variety of compounds. The carbon-fluorine bond is one of the strongest chemical bonds. These plastics have unique physical and chemical properties and are chemically inert, water-repellent, fire-, temperature- and weather-resistant. As a result, well-known halogen compounds such as PTFE or PVC have become a permanent part of modern applications. However, these properties also mean that they are non-degradable during usage and in the environment. If they continue to be released, they can accumulate in the environment, in drinking water and in food. Current recycling processes are technically complex and not very effective. Where possible, halogenated compounds are only recovered from the flue gases. This destroys the structure of the carbon skeleton. The Halocycles project is developing a new method to recover halogens. An electrochemical process instead of using thermal energy presents a completely new perspective. The electric current reduces the halogen atoms, creating halide anions in which the carbon structure is retained and which are therefore available as a source of raw materials for various chemical processes. This process is designed to use surplus electricity while helping to stabilize the power grid.

Recycled halogen polymers are analyzed in detail to determine the material properties and transfer them into a more resource-efficient circular economy.

The main goal of the project is to describe the properties of the recycled halogen polymers in detail. For this purpose, extensive analyzes are carried out in order to gain a profound understanding of the material properties. These findings serve as a basis for effectively integrating the recycled halogen polymers into the circular economy.



The project "HaloCycles – Sustainable Cycles for PFAS Enabled by Electrochemistry" is funded by the Carl-Zeiss-Stiftung.

Carl Zeiss Stiftung

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IVW-Research Data Management

Andreas
Gebhard

Research data is an indispensable component of the scientific knowledge-building process. As a member of the Leibniz-Association, IVW shares their view that making research data accessible is an equally valuable scientific achievement as the traditional publication of aggregated data and conclusions. To meet this goal and, at the same time, significantly enhance the initial and long-term benefits of research data at IVW, the IVW Research Data Management Handbook came into effect on May 1, 2023. This handbook serves as a guide for IVW researchers in the collection, storage, utilization, and publication of research data. In addition to an institute-wide introductory lecture, many IVW researchers also took advantage of the subsequent workshops to learn about the goals and structures and to learn the specific practices of research data management.


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Metadata file (excerpt) of a research dataset published by an IVW researcher

The program initially focused on the creation of research data plans, the practical organization of research data, and the revision control of research software. For the cornerstone of research data management-metadata-training was provided for both manual creation and the use of the Python programming language, and these resources were widely utilized. Furthermore, the institute's own laboratory information system PKDE was expanded to significantly simplify the collection and use of metadata records.

As a result, IVW researchers have already realized a central objective of research data management: articles in scientific journals have been published with accompanying experimental datasets, simulation results supplemented with metadata have been published as independent datasets, and scientific software has also already been made accessible to a global audience.

Antimicrobial / Antiviral Protection on the Nano-Level

SUSAAN
SUStainable Antimicrobial and Antiviral Nanocoating

Surfaces and objects contaminated with bacteria can cause illness. The COVID 19 pandemic has shown the importance of improving surface cleaning and hand hygiene to reduce infections. Viruses and bacteria are found on many surfaces, including cell phones, elevator buttons (which harbor 22% more bacteria than toilet seats), light switches, door handles, textiles, and other high-traffic items in hospitals, nursing homes, schools and daycare centers, kitchens, and restrooms. For the textiles, plastic and metal surfaces used there, the development of sustainable antimicrobial and antiviral nanoactive coatings can significantly reduce the risk of pathogen contamination and infection. In the EU project SUSAAN, IVW is developing (hybrid) nanocapsules (NC) containing different antimicrobial/antiviral (AN/AV) active materials such as essential oils and metal oxides.

By encapsulating the active ingredients in polymer capsules, they can be protected from degradation and their activity can be prolonged. The chemically functionalized and partially cross-linked biogenic polymer of the capsule increases the encapsulation efficiency and release profile of the contained substances. The binding to the coating polymer and substrate surfaces, as well as the stability and storability are also improved. NCs are synthesized using "green chemistry" methods and principles. The manufacturing process, the type of particle modification and the formulation of the AM/AV components are tailored with respect to functionality, coating material and substrate. With the aim of using the functional coatings in products, the project partners are cooperating along the entire process chain from fundamental chemical research to the finished component.

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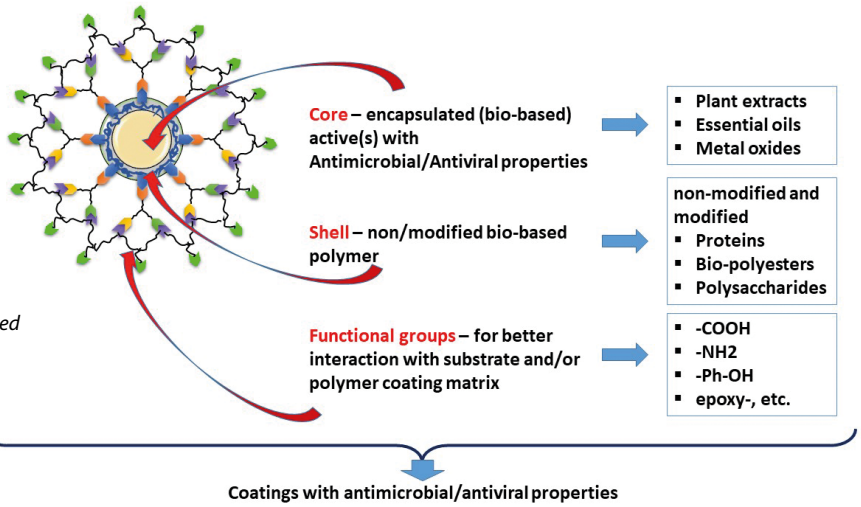

Structure of the core-shell nano-capsule with encapsulated antimicrobial/antiviral active

Partners

- *Almaxtex Tekstil Sanayi Ve Ticaret Anonim Sirketi (TR)*
- *Association pour la Recherche et le Developpement d'Innovations et de Technologies pour la Protection de l'Heritage Environnemental, Social (FR)*
- *Asociacion Centro Tecnologico Ceit (ES)*
- *Celabor Scrl (BE)*
- *Eczacibasi Yapi Gerecleri Sanayi ve Ticaret A.S. (TR)*
- *Instituto Tecnologico del Embalaje, Transporte y Logistica (ES)*
- *Intertek Iberica Spain Sa (ES)*
- *Intertek Italia Spa (IT)*
- *L'UREDERRA, Fundacion para el Desarrollo Tecnologico y Social (ES)*
- *National Center for Scientific Research „Demokritos" (Greece)*
- *Panasonic Life Solutions Elektrik Sanayi Ve Ticaret Anonim Sirketi (TR)*
- *Tecnologia Navarra de Nanoproductos Sl (ES)*
- *Virhealth (FR)*

The project "SUSAAN – SUStainable Antimicrobial and Antiviral Nanocoating" is funded by the European Union (GA No 101057988). Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or HADEA. Neither the European Union nor the granting authority can be held responsible for them.

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Partner cltech HIGHTECH HOLZBAU

Modified and Compacted High-Performance Wood from Native Wood Residues for Structural Components

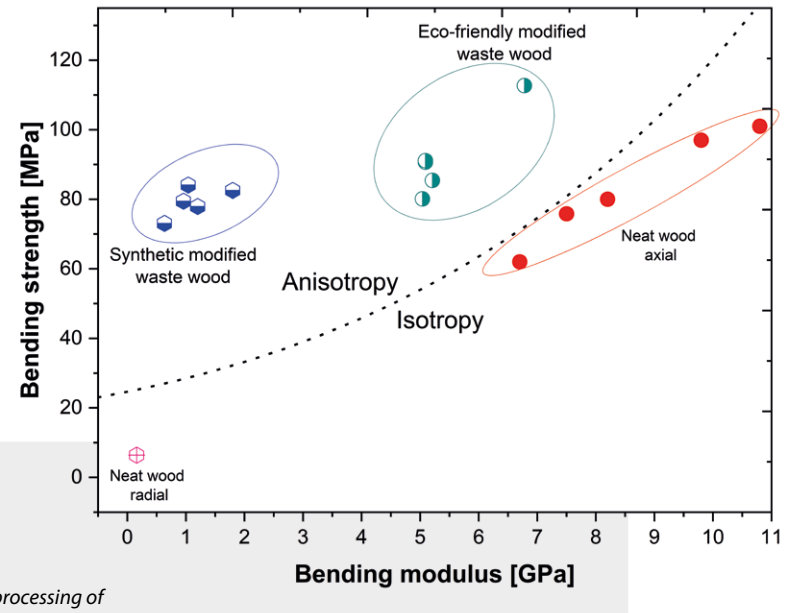
Emmanuel Akpan

Wood is a valuable, renewable and sustainable material with excellent functional properties and the potential to replace fossil materials in lightweight composite materials. Wood processing generates large amounts of waste such as offcuts, chips and sawdust. Like all other products, wood products eventually reach the end of their life cycle and are disposed of as waste. The global use of wood has increased significantly in recent years, resulting in more and more wood waste.

An improvement of the material cycle in the context of the circular economy for wood materials is desirable, since currently about 79% of wood waste is still incinerated and about 5% is landfilled. Existing recycling processes for waste wood require the use of harmful chemicals and binders. "Waste2Wood" focuses on developing an innovative approach to producing wood-based materials from wood waste using sustainable technology.

SEM image showing the fracture surface of the processed material.

The goal is to develop environmentally friendly chemical and biotechnological processes to modify the biopolymer matrix of wood waste to enable further processing into semi-structural composites without additional binders. An immediate application is the use of the material as a new component in cross-laminated timber with multi-material design to reduce volume by 40%. Initial results show that a highly anisotropic material can be produced with mechanical properties comparable to or better than natural wood and WPCs. Further approach includes in situ de/repolymerization of lignin as a binder to achieve even better mechanical and physical potentials for further technical applications.



Sustainable processing of waste wood (particles) results in better mechanical properties.

SPONSORED BY THE
Federal Ministry of Education and Research

The project "Waste2Wood – Modified and compacted high-performance wood from native wood residues for structural components" is a development project in the Programme "Waste2Value" funded by the Federal Ministry of Education and Research (BMBF).

Composites Laser Cutting

A new "TruLaser Cell 7040" laser processing center from TRUMPF has been available at IVW since 2020. It enables the processing of various composite materials with millimeter precision. The machine's beam source is a high-quality "TruFlow" laser with a maximum laser power of 5 KW.

The laser cell allows to cut composite materials of any shape quickly, precisely and efficiently, and thus prepare them for a wide range of further processing. The machine itself works on the principle of flying optics, whereby the processing optics move around the stationary component. Processing can be carried out in 2D or 3D, with a maximum working range (2D) of 1500 to 2000 mm. Both welding and cutting optics are available as processing optics. The maximum simultaneous axis speed is 173 m/min. The positioning accuracy of the linear axes (X, Y, Z) is 0.08 mm and that of the rotary axes (B) is 0.015°.

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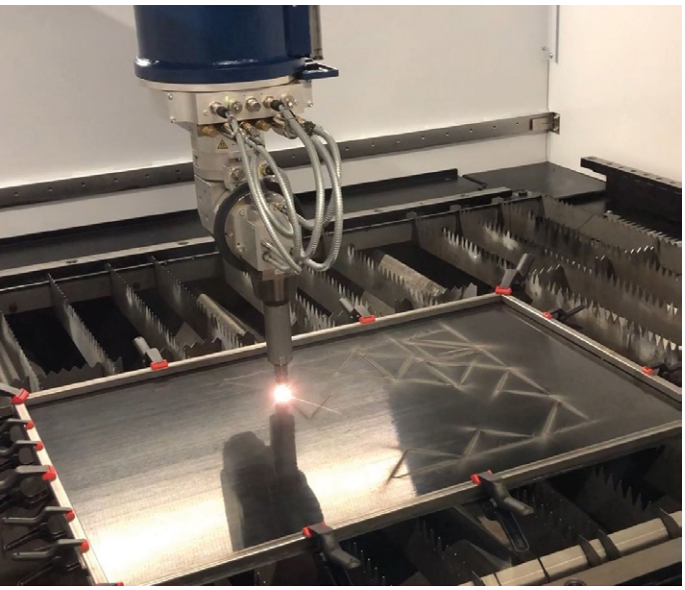
Application of cutting optics:
Pure plastics (PA, PMMA, PP, etc.), glass fiber and natural fiber organo sheet, glass fiber fabric.

Application of welding optics:
Carbon fiber organo sheet cutting, carbon fiber fabric cutting.

The laser is a "TruFlow" CO_2 laser with a wavelength of 10.6 µm. The laser power can be adjusted depending on the application ensuring a clean cut edge. Thanks to the adjustable power bandwidth and the excellent laser beam properties, the CO_2 laser can produce both fine and coarse cuts. A pilot laser is also available for workpiece positioning and for the teaching function.



Organo sheet cutting

Technical data	
X axis travel range	2000 mm
Y axis travel range	1500 mm
Z axis travel range	750 mm
B axis travel range	135 °
C axis travel range	360 °
Maximum axis speed, simultaneous	173 m/min
Positioning accuracy of linear axes (X, Y, Z)	0,08 mm
Positioning accuracy of rotary axes (B)	0,015 °
Maximum laser power	5000 W
Beam source	CO2 Laser – Type „TruFlow"
Available optics	welding and cutting optics
Extraction system	specified to process composite materials
Processing possibilities	2D and 3D

Technical Data TruLaser Cell 7040

Multiphysical Modeling of Shape Adaptive Composites

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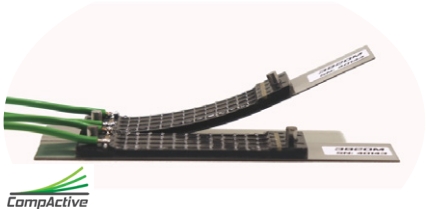
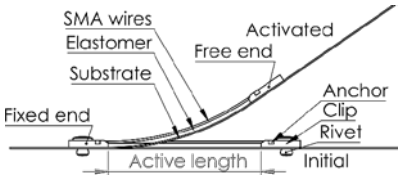
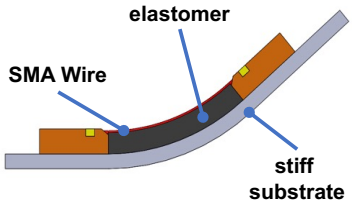
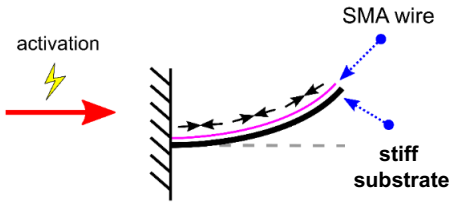


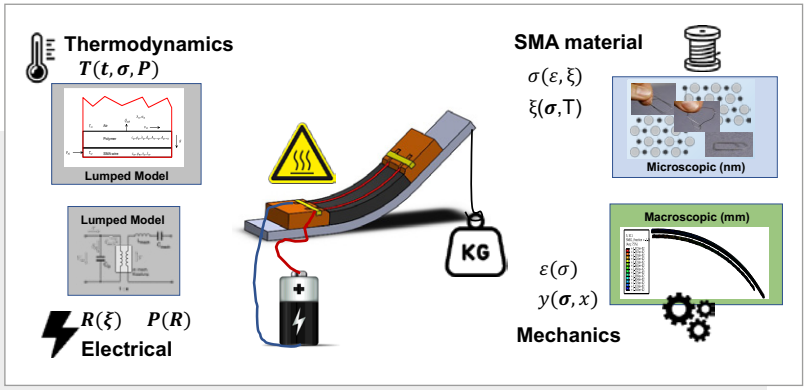


General purpose SMAHC Actuators





Shape Memory Alloy Hybrid Composite-Actuators offer the possibility to convert electrical or thermal energy into mechanical deformation. The active material hereby is a metallic shape memory alloy in form of thin wires. Their applications range from gap and kink-free aerodynamic elements, e.g. in aeronautics or automotive industry, to material-integrated actuators in general engineering. In the past, applications such as a morphing trailing edge, active vortex generators, smart air vents or locking and unlocking mechanisms have already been developed in numerous projects, mostly based on an empirical basis. IVW has now established an universally applicable multiphysical model that enables the systematic development of applications in all target areas [1]. A highlight of the model is its ability to predict not only the maximum actuation force and deflection, but also the expected energy demand for a wide range of environmental conditions. The model is based entirely on freely available software and can be used for non-commercial purposes at any time. The source code, together with a data set for validation [3], is available at [2].



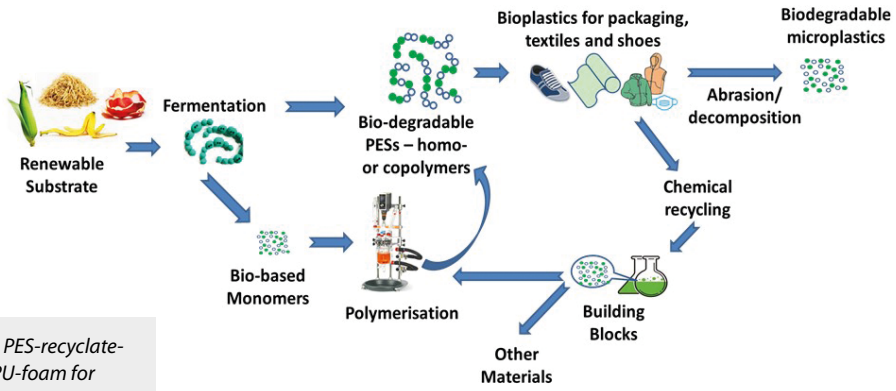
Multiphysical Model for Shape Memory Alloy Hybrid

[1] M. Kaiser, M. Kunzler, and M. Gurka, Experimentally Characterization and Theoretical Modeling of the Electro-Thermomechanical Coupling of Unimorph Shape Memory Active Hybrid Composites, Composites Science and Technology 242, 110186 (2023).

[2] M. Kaiser, sa_smahc_py, (2023), GitHub repository, https://github.com/KaiMa92/sa_smahc_py

[3] M. Kaiser, M. Gurka, SMAHC characterization under influence of external load and ambient temperature, Dataset, ZENODO (2023) http://dx.doi.org/10.5281/zenodo.7762701

New Bio-Based Polyesters for Biodegradable Textile, Packaging and Footwear Applications



Bio-based, PES-recyclate-containg PU-foam for shoe insoles

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Microplastic accumulates and remains in the environment. It is difficult to biodegrade. It has been found in oceans, freshwater ecosystems, and human and animal tissues and organs. The packaging, textile and footwear industries are among the main sources of pollution, e.g. from packaging waste, textile laundering and shoe abrasion. Therefore, new biogenic and biodegradable polyesters (PES) (incl. polyhydroxyalkanoates, PHAs) are being developed for these applications and low-risk biogenic resources (incl. biomass waste streams) are being used in the supply chain. Polymers are also being optimized for multiple recycling. Sustainability (LCA) and toxicity assessments are performed at all stages of development.

IVW is working with members of the Waste2BioComp consortium specifically to prevent premature degradation of PES and growth of bacteria and fungi. This is accomplished by the chemical modification of the developed PESs and proteins and using them to nanocapsulate biogenic antimicrobial/antifungal (AM/AF) agents. The nanocapsules produced are incorporated into packaging materials, textile coatings, and foams for shoe soles. An essential step towards the circular economy is the recycling of plastic waste and the reuse of the recyclates in new products. Chemical recycling of PES at end-of-life occurs, on the one hand, through hydrolysis to monomers/oligomers and subsequent chemical and/or biotechnological PES synthesis (in the case of PHA). In addition, chemolysis of PES to PES-diols yields chemical components for polyurethane (PU) foams for shoe soles, among other applications.

For technology demonstration, bio-based packaging films, nonwoven coatings for sportswear, and foams for shoe soles are produced.

Synthesis of biobased and bio-degradable polyesters and their application

Partners

- *CITEVE - Centro Tecnológico das Indústrias Têxtil e do Vestuário de Portugal*
- *INESC TEC – Instituto de Engenharia de Sistemas e Computadores, Tecnologia e Ciência*
- *Hochschule Kaiserslautern*
- *Universidade da Coruña*
- *MAGELLAN - Associaço para a Representacção dos Interesses Portugueses no Exterior*
- *MTEX New Solution SA*
- *NIXKA*
- *PILI*
- *Propagroup SPA*
- *Nora systems GmbH*
- *Riopele – Têxteis, SA*
- *GR3N SAGL*

The project "Waste2BioComp – Converting Organic Waste into Sustainable Bio-Based Components" is funded by the European Union (GA No 101058654).

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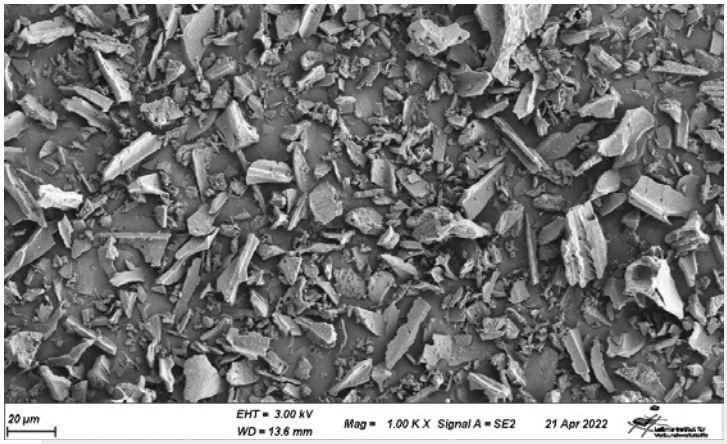
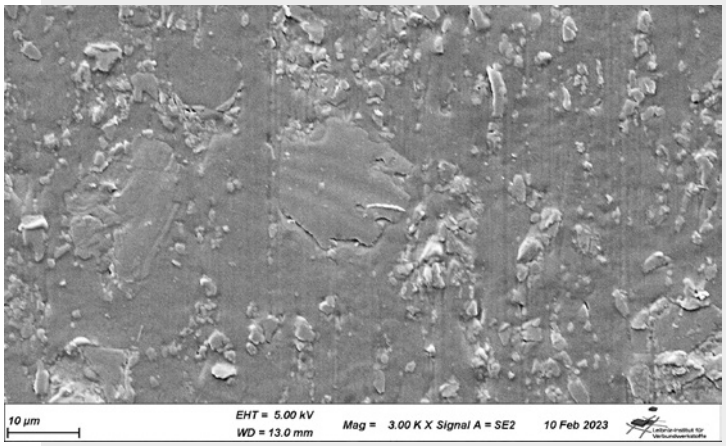
Partner ATB Leibniz-Institut für Agrartechnik und Bioökonomie

Tribological Properties of Polymers with Bio-Carbon Lubricants

Andreas Gebhard

The production of replacement parts for worn components still consumes more primary energy than, for example, the entire aviation industry before the COVID-19 pandemic. In order to manufacture tribological plastics in line with climate goals and within the remaining CO_2 budget, their consistent decarbonization is essential. While biobased polymers are already on the market, tribologically critical solid lubricants such as graphite and polytetrafluoroethylene (PTFE) are still very CO_2 and energy-intensive. In the case of PTFE, there are also concerns regarding long-term health and environmental damage ("forever chemicals").





Pyrolyzed and ground coconut fibers

Therefore, biobased alternatives to graphite and PTFE were investigated in collaboration with the Leibniz Institute for Agricultural Engineering and Bioeconomy (ATB). Agricultural byproducts were pyrolyzed to increase their carbon content, then ground and processed into a composite material with a polyamide 6 matrix.

Dry sliding tests against steel showed that these materials exhibited friction coefficients and wear rates only slightly higher than those of a reference material with fully synthetic graphite. The sliding surfaces had only minor grooves in the sliding direction and no signs of disruption. Measurements of the transfer film formation demonstrated that significantly less abrasion adhered to the steel counterpart compared to synthetic graphite, which explains the observed absence of adhesive damage and fatigue, as well as the lower contribution of adhesion to overall friction.

IVW and ATB are planning a joint cooperation in publicly funded projects with the industry in order to promote the use of composite materials with biobased solid lubricants in industrial applications.

Correlation of Matrix Properties to the Fatigue Behavior of Fiber Reinforced Polymers

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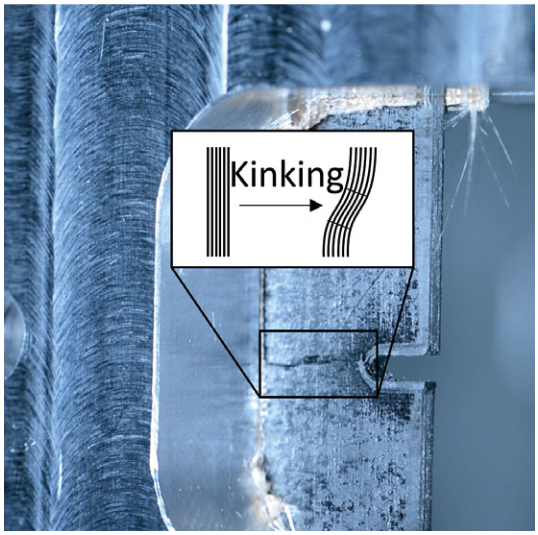
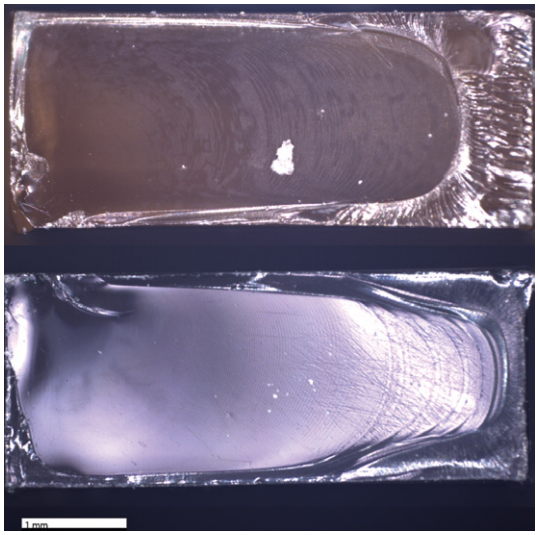
Continuous fiber reinforced materials are a class of materials with exceptionally good fatigue properties, due to the durability of the fibers under cyclic loading. However, the polymer and the fiber-matrix interface are basic prerequisites to utilize these properties in a composite. The initiation can be, for example, a small crack or an increased fiber misalignment under compressive loading, due to lacking support from the matrix. Even though these damage mechanisms are typically on a microscale, it is established that this initial damage grows and threatens the laminate's integrity on a macroscale. The identification of matrix properties that drive the damage formation is a challenging task, because most changes on the polymer level lead to undesired changes in the laminate as well. High-energy radiation could remedy this situation because most undesired changes such as differing geometric arrangement of the fibers can be avoided, as this treatment is the final step in specimen preparation. An initial screening of different polymers from both classes of thermosetting and thermoplastic polymers lead to epoxy resin and polycarbonate as modifiable polymers used also in composites. Designated lay-ups and specimen geometries are used to make the material prone to specific damage modes like fiber kinking in compression or transverse matrix cracking in tensile loading. Special testing set-ups enable the in-situ observation of damage during formation. It has been shown that in some circumstances damage already forms within the first loading cycle at relatively low global strain. A currently ongoing systematic testing campaign of transverse tensile-tensile loading, on-axis compression-compression loading and alternating shear loading will build the database to facilitate a better understanding. Complementary micromechanical models support this effort.



Notched on-axis compression specimen for the initiation of kink bands (local instability)



Radiation induced changes in fracture surface (top irradiated/ bottom pristine)

The project "Correlation of matrix properties to the fatigue behavior of fiber reinforced polymers" is funded by Deutsche Forschungsgemeinschaft (DFG, German Research Foundation) – 468045930.

TPC-H2-Storage – Pressure Vessels for Hydrogen Storage and Transport

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The project aims to develop lightweight construction methods for manufacturing fiber-reinforced polymer (FRP) piping for hydrogen distribution and tanks for hydrogen storage in aircrafts. The focus is on systems for both, cryo-compressed (CcH_2) and liquid hydrogen (LH_2) distribution and storage. To maintain the required temperature of below -253°C, a double-wall FRP construction is used for the tank and the pipeline (Figure 1). The inner cylinder stores hydrogen and handles internal pressure, while the outer shell provides thermal insulation and connectivity to surrounding systems. The inner cylinder and outer shell are mechanically decoupled, allowing the tank/pipeline to serve as a structural load-bearing component, for e.g., a replacement for spar and stringers in an aircraft wing (Figure 2). For this purpose, an effective suspension and insulation system is being explored to keep the heat and load transfer away from the inner tank/pipeline. The main focus at IVW is on the development of a tank/pipeline and a suspension system that is capable of absorbing the loads from the outer shell without transferring them into the inner tank. Structural foams are being explored for use as suspension system. Initial testing of a composite pipeline with foam suspension and N_2 as a medium is under development. The project builds on the design of a novel lightweight hydrogen pressure tank patented at IVW. In the patented design, the loads in the carbon fiber-reinforced polymer (CFRP), which occur due to the high pressure for storing CcH_2, are transferred by metallic boss parts. The low temperature of CcH_2 leads to the shrinkage of the metallic parts. To avoid the shrinkage and, therefore a leakage of the pressure vessel, the metallic parts are pre-tensioned. In the case of the LH_2 distribution system, thin-walled braided FRP-pipes are planned for the inner pipeline due to low operating pressures.

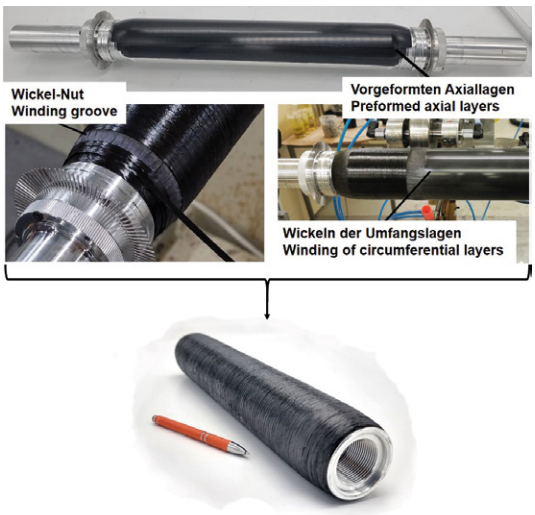

Figure 1: Final design of the thermoplastic hydrogen pressure tank (bottom) and the manufacturing process (top)

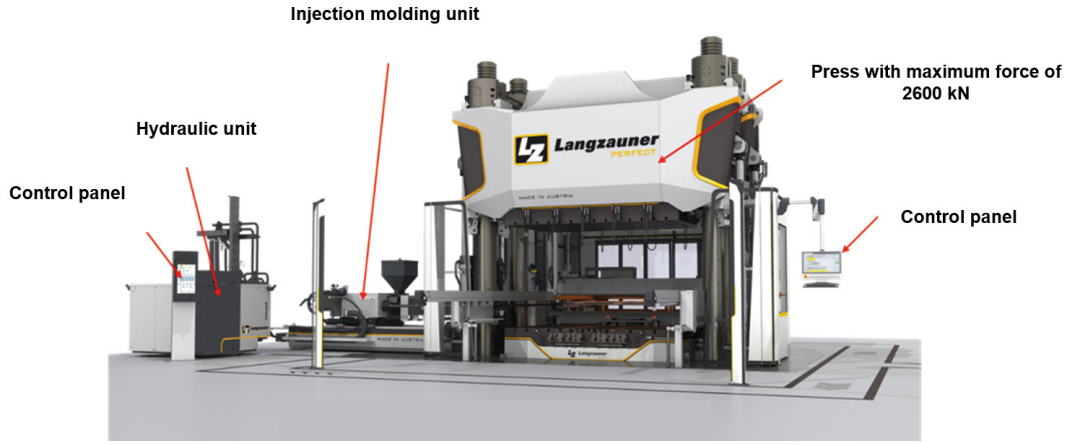

Figure 2: Overall plant concept of the LZT-UK-2600-S multiple injection molding and forming plant

The project "Infrastructure development for thermoplastic fiber composite pressure vessels for hydrogen storage and hydrogen transport (TPC-H2-Storage)" was funded by the European Regional Development Fund (ERDF) and the Ministry of Science and Health (MWG) (funding reference 84009883).

CF-Hydro – FRP-based Hydrogen Transportation and Storage

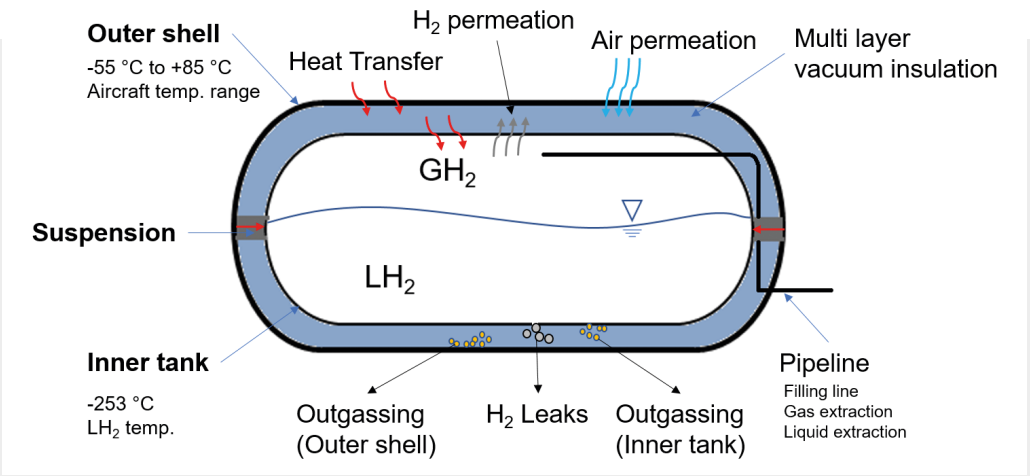

Figure 1: A schematic of a double-wall FRP construction for cryogenic storage of H2, showing various challenges and problems to resolve.

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The CF-Hydro project aims to develop lightweight construction methods for manufacturing fiberreinforced polymer (FRP) piping for hydrogen distribution and tanks for hydrogen storage in aircrafts.

The focus is on systems for both cryo-compressed (CcH2) and liquid hydrogen (LH2) distribution and storage. To maintain the required temperature of below -253°C, a double-wall FRP construction is used for the tank and the pipeline (Figure 1). The inner cylinder stores hydrogen and handles internal pressure, while the outer shell provides thermal insulation and connectivity to surrounding systems. The inner cylinder and outer shell are mechanically decoupled, allowing the tank/pipeline to serve as a structural load-bearing component, for e.g., a replacement for spar and stringers in an aircraft wing (Figure 2). For this purpose, an effective suspension and insulation system is being explored to keep the heat and load transfer away from the inner tank/pipeline. The main focus at IVW is on the development of a tank/ pipeline and a suspension system that is capable of absorbing the loads from the outer shell without transferring them into the inner tank.

Structural foams are being explored for use as a suspension system. Initial testing of a composite pipeline with foam suspension and N2 as a medium is under development. The project builds on the design of a novel lightweight hydrogen pressure tank patented at IVW. In the patented design, the loads in the carbon fiber-reinforced polymer (CFRP), which occur due to the high pressure for storing cryo-compressed hydrogen (CcH2), are transferred by metallic boss parts. The low temperature of CcH2 leads to the shrinkage of the metallic parts. To avoid the shrinkage and, therefore a leakage of the pressure vessel, the metallic parts are pre-tensioned. In the case of the LH2 distribution system, thin-walled braided FRP-pipes are planned for the inner pipeline due to low operating pressures.

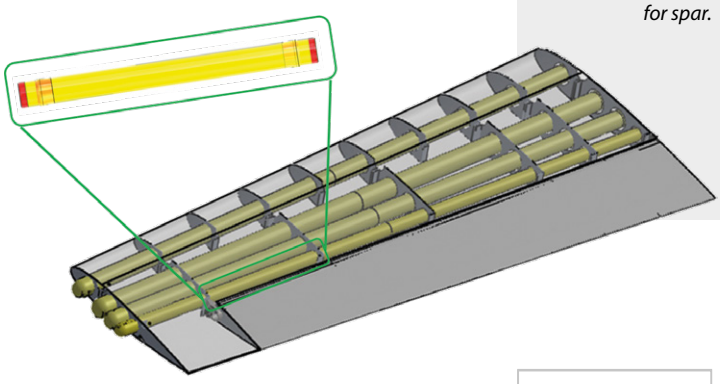

Figure 2: The structural load bearing H2 pipeline developed at IVW, as a structural member in an aircraft wing for e.g. as replacement for spar.

The project "Development of an integrated FRP-based hydrogen storage and distribution system for aerospace applications – CF-Hydro" is funded by the Federal Ministry for Economics and Climate Action on the basis of a decision by the German Bundestag (funding reference 20E2103).

Supported by:
Federal Ministry for Economic Affairs and Climate Action
on the basis of a decision by the German Bundestag

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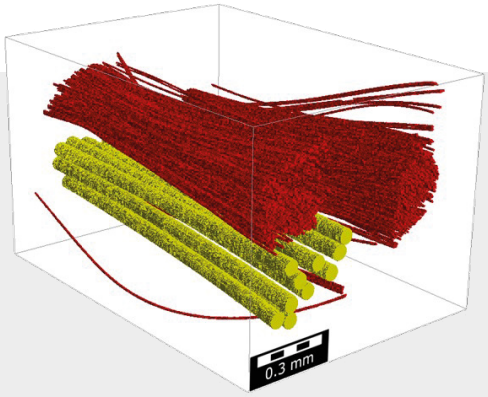
Partner ITM LEADING IN FIBRE & TEXTILE TECHNOLOGY Forschungsinstitut der Exzellenzuniversität

Homogeneous Steel-Glass Thermoplastic Fiber Hybrids with High Structural Integrity

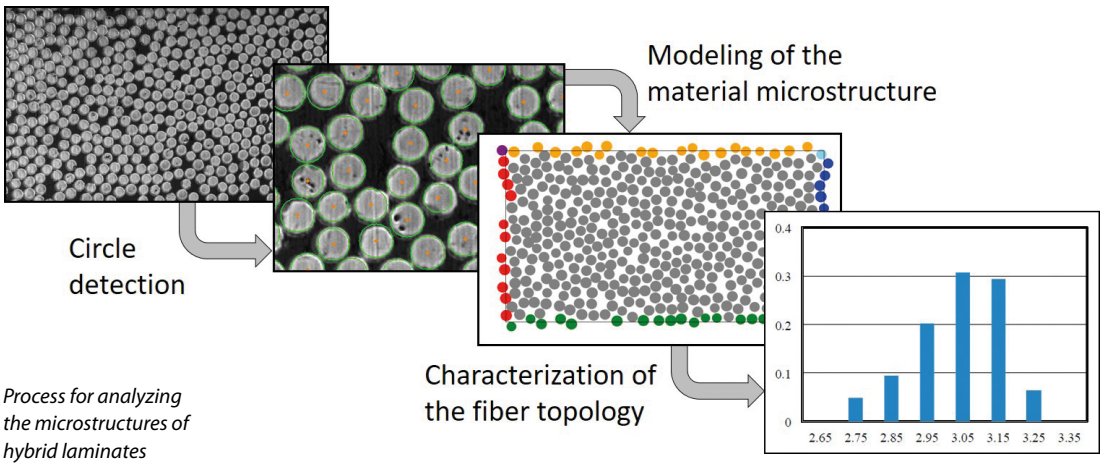
Jan Rehra

Due to the selection, modification and composition of different plastics and reinforcing fibers, fiber reinforced plastics (FRP) offer unique possibilities regarding the design of tailored and optimized component properties. It can be shown that, for example, the combination of steel fibers and classic reinforcing fibers within a hybrid FRP enables the direction-dependent modification of mechanical and fracture-mechanical properties in a wide rrange. In particular, the energy absorption associated with failure depend, among many other propertys, on the hybridization strategy used and the resulting microstructure of the material. While previous investigations were mainly focused on the investigation of FRP hybridized on single-layer level, the current work focuses on the manufacturing, characterization and description of FRP hybridized at the yarn level. For this purpose, three-phase hybrid filament yarns are produced from glass, steel and polypropylene filament yarns by the use of a modified air-texturing machine. These hybrid yarns are further processed to hybrid laminates by the use of winding and press technologies.

In order to characterize the influence of this new possibility to adjust the material microstructure as well as the resulting consequences for the mechanical behavior, in addition to the experimental investigation, a detailed numerical material characterization is carried out using representative volume elements.



3D scan of a hybrid yarn microstructure



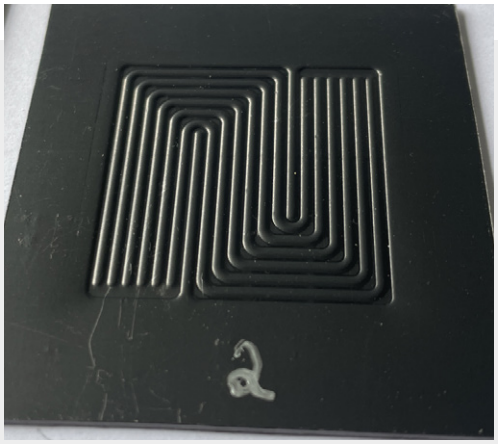
Process for analyzing the microstructures of hybrid laminates

DFG Deutsche Forschungsgemeinschaft

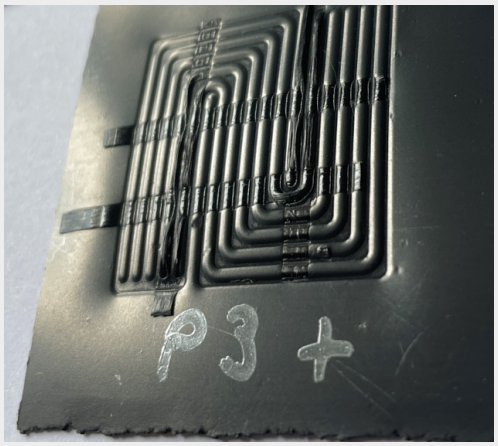
The project "TriPhaHyb: Homogeneously dispersed steel-glass-thermoplastic fiber hybrid composites with ductile material behavior and high structural integrity" is funded by the German Research Foundation (DFG) (441549528).

Partner

Fiber Reinforced Compound Foil Bipolar Plates for Compact Light Fuel Cells



1



2

Formed bipolar plate from a compound foil.
(1) no fiber reinforcement,
(2) incorporated fiber tapes.
Active area of these samples: 30 x 30 mm²

Hydrogen fuel cells are considered to be one approach for substituting fossil fuels in, for example, the automotive industry. Fuel cells consist of multiple bipolar plates which, due to their complex requirements, are made of either coated metals or polymers filled with graphite → graphite polymer compounds. The advantage of the compound bipolar plates is the missing expensive coating which is crucial for the lifetime of metallic bipolar plates. However, the injection molding process and the inferior mechanical properties of the compounds yield in a high wall thickness which increases the volume and decreases the power density of the fuel cell. To oppose these disadvantages, thin compound foils are reinforced with carbon fibers in this project. The fibers are incorporated into the bipolar plate by using press processes while the undulated bipolar plate is formed from the flat compound foil. Furthermore, the materials are characterized for their mechanical properties for a FE simulation to be performed. This simulation is essential for the design of the necessary fiber reinforcement so the bipolar plate can withstand the external and media pressures during the assembly and service life of the fuel cell.

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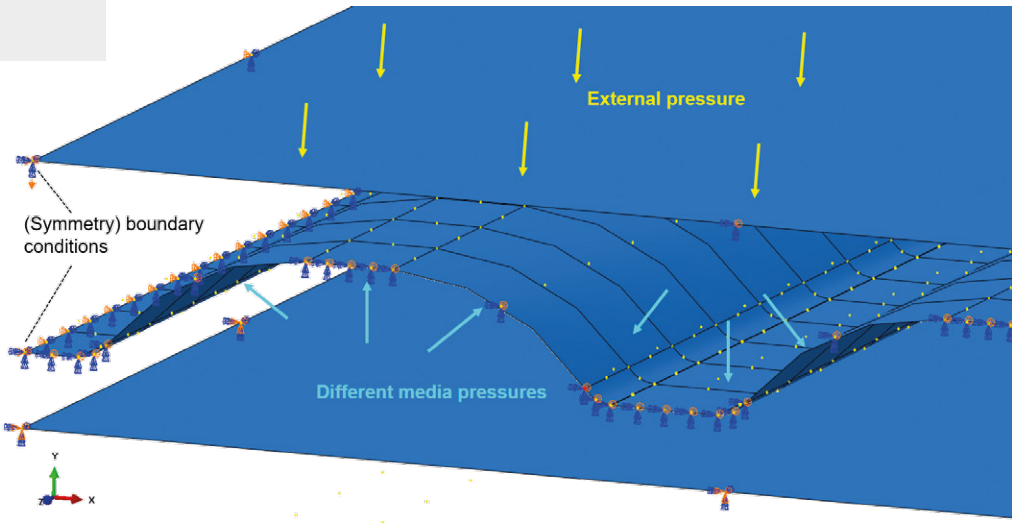

Simulation model of a single bipolar plate using shell elements. Besides the external pressure for positioning, the plate has to bear media pressure within the channels. Due to symmetric boundary conditions the simulation can be performed on a sub structure. The wave length of the bipolar plate shown is < 2 mm.

The project "Fiber reinforced compound foil bipolar plates for compact fuel cells" is funded by the Federal Ministry of Economics and Climate Action on the basis of a decision by the German Bundestag (funding reference 22342 N).

Supported by:
Federal Ministry for Economic Affairs and Climate Action
on the basis of a decision by the German Bundestag

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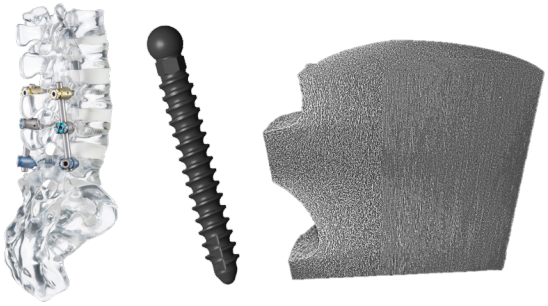
Activities in the Medical Sector

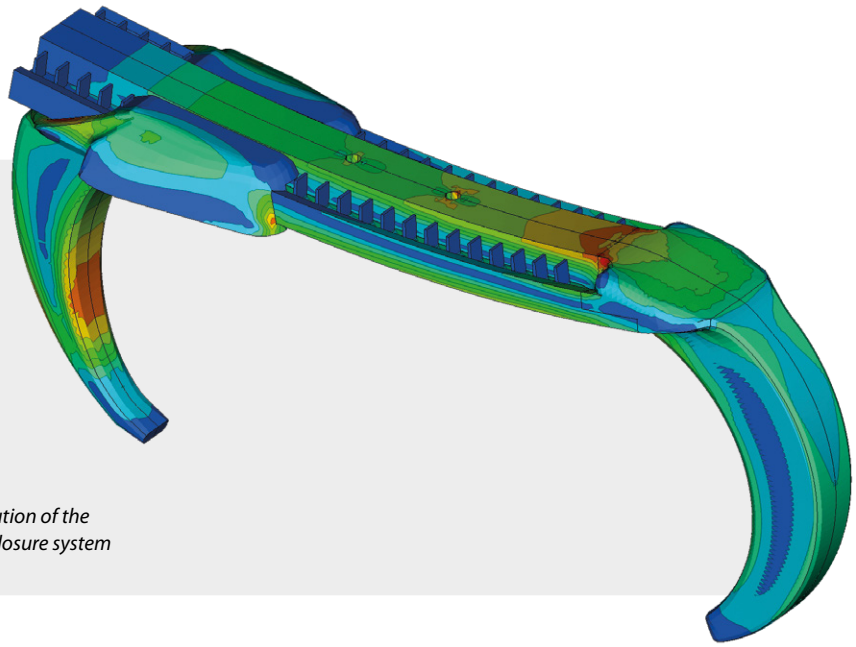
Janna
Krummenacker

The demand for solutions made of fiber-reinforced plastics (FRP) in the medical sector is constantly increasing. FRP is suitable for medical applications particularly thanks to its biocompatibility, the possibility to adapt the stiffness, and its X-ray transparency. In recent years, the IVW has developed promising products in this area, both in the field of implant technology and in the field of therapeutic devices. For example, within the framework of an EU-funded project, a pedicle screw system made of fiber-reinforced plastic (FRP) was developed to increase patient comfort and improve post-operative follow-up care („HySpine“). The development of an aneurysm clip takes advantage of the radiolucency of fiber-reinforced plastic, so that the position of the implant can be checked using imaging techniques („InnoClip“). In the project “FIXTER”, a low-cost, easy-to-use closure system was developed for fixing the two halves of the sternum after a median sternotomy. In the orthopedic technology sector, a method was developed to produce individualized ankle orthoses using 3D printing processes and then reinforce them with thermoplastic fiber tapes („3Dprint2Fiber“).

IVW is currently working together with the RPTU on the “Citizen Science” project “BewegungsForscher” as part of the joint project “Offene Digitalisierungsallianz Pfalz”. During the project period from 2023 to 2027, everyday health tools will be developed. The project stands out for its intensive collaboration with citizens, who are involved in the development process as users, relatives, care staff, medical personnel and stakeholders at all stages of the project.



Pedical screw system made of continuous and short fiber reinforced PEEK



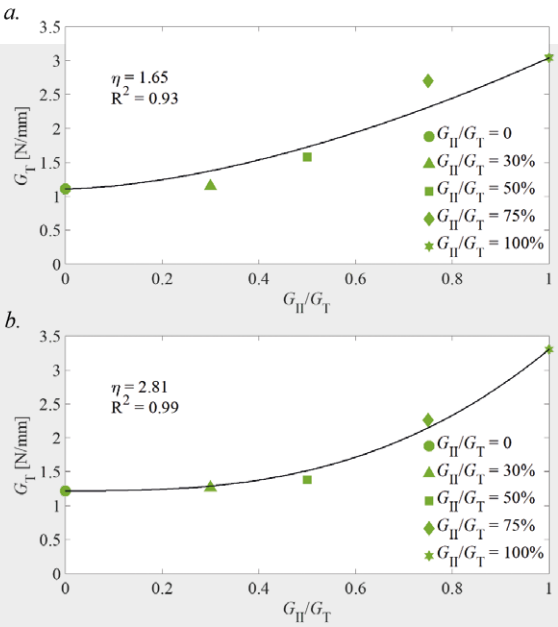
Stress distribution of the STERN FIX© closure system

SPONSORED BY THE
Federal Ministry of Education and Research

The project “Offene Digitalisierungsallianz Pfalz II – Teilprojekt IVW im Teilvorhaben Citizen Science” is funded by the Federal Ministry of Education and Research on the basis of a decision by the German Bundestag (funding reference 03IHS254D).

Partner engineers Hamburg

FAnTeStick – Fatigue Analysis and Test Procedures for the design of Bonded Joints



Evolution of the experimental fracture envelope and B-K criterion for a. Q Series [-45°/90°/45°/0°] s2 and b. B Series [0°/90°/90°/0°]s

The FAnTeStick project focuses on the experimental evaluation of the fracture and fracture/fatigue behavior of GFRP adhesively bonded joints. Two different stacking sequences were evaluated.

The goal of the test campaigns was to characterize the complete mixed-mode I+II fracture envelope to use as a base for developing a predictive numerical tool. For both layups, the quasi-static results were similar; with a deviation of 10% for the pure modes and less than 5% for mixed mode I+II. The Benzeggagh-Kenane (B-K) fracture criterion was used to describe the full mixed-modes I+II fracture envelope. The B-K method relates the experimental total energy release rate results as a function of the mixed mode ratio. Such criteria proved to be highly accurate to predict the mixed-mode fracture behavior. In fact, for both series, a coefficient of determination above 0.93 was obtained. Similarly, a numerical model was employed to describe the quasi-static fracture behavior by using the cohesive zone model with a linear softening relation as the traction-separation law. This modelling proved to be efficient in describing the observed experimental behavior. For loading modes with a predominance of mode I, the numerical model proved to be even more reliable and accurate.

In the case of the fatigue characterization, the goal was to determine the fatigue life and a modified Paris law representative of the fatigue fracture behavior of both series. Fatigue tests were carried out under pure tensile and shear loading. A power law was fitted to the crack propagation experimental data in order to obtain the best fit for the Paris law shape parameters. For both stacking sequences similar shape parameters were achieved.

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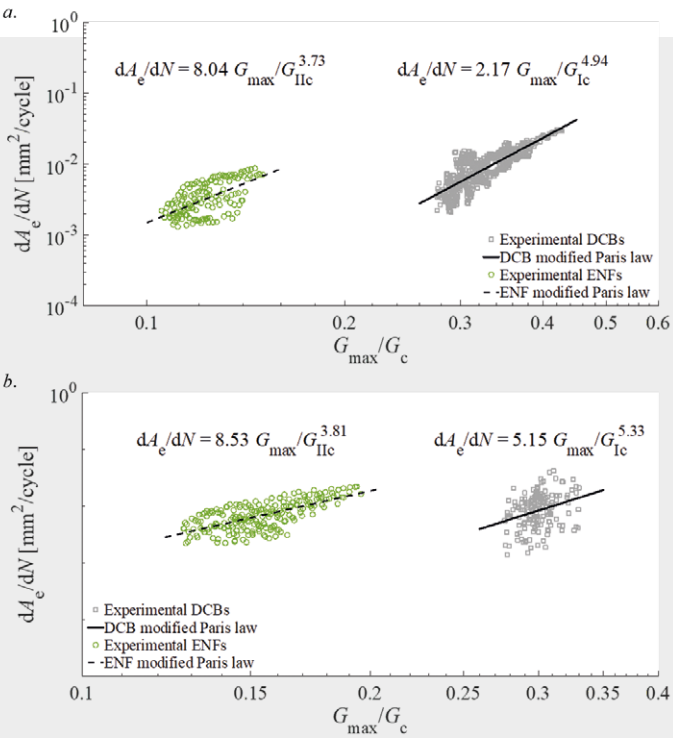

Experimental crack propagation results and adjusted global modified Paris law for: a. Q Series [-45°/90°/45°/0°] s2 and b. B Series [0°/90°/90°/0°]s

The project "FAnTeStick – Fatigue Analysis and Test Procedures for the Design of Bonded Joints" is funded by the Federal Ministry for Economic Affairs and Climate Action on the basis of a decision by the German Bundestag (funding reference KK5003702EB0).

Supported by:
Federal Ministry for Economic Affairs and Climate Action
on the basis of a decision by the German Bundestag

WaVe – Innovative FRP Tank Structure for Hydrogen Storage

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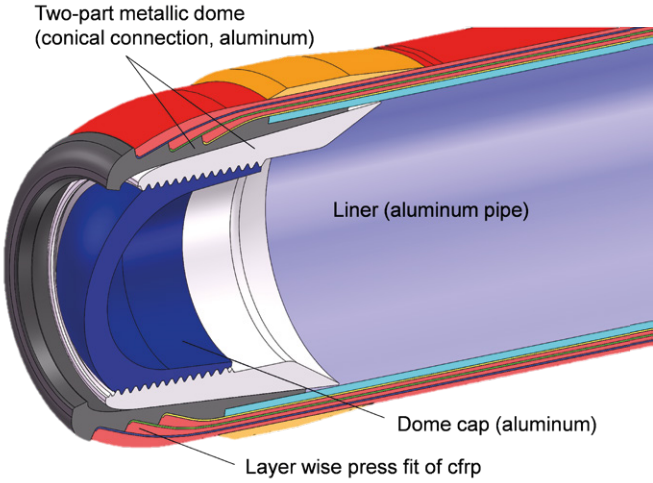
As part of the WaVe project, IVW is developing a lightweight-optimized CFRP pressure tank design for storing gaseous hydrogen. Currently, the supply of H_2 to the newly developed hydrogen combustion engine in the UNIMOG demonstrator, which has recently obtained road approval, is facilitated by four conventional Type-4 tanks. Initially, this research vehicle provides about 13 kg of stored H_2. The goal of the WaVe project is to increase this H_2 capacity in the UNIMOG to about 28 kg, while maintaining the same space requirements on the vehicle. In the future, the lightweight tank modules will efficiently utilize the available space and provide the necessary quantity for regular operation.

A novel manufacturing process is being developed to create cylindrical pressure vessels with purely axial and circumferentially applied fibers. These vessels possess maximum lightweight design qualities and can be manufactured with very small diameters. The load transfer from the axial layers in the cylindrical section of the pressure vessel is achieved layer by layer using the patented "IVW load introduction". This method allows for the proper integration of the metal dome regions to carry the load. In contrast to the conventional approach, where a preformed "plastic bladder" is used as the liner, a metal or plastic tube can be utilized as a liner.

Additionally, an O-ring is installed to enhance sealing. Initial prototypes have been manu-factured and subjected to burst testing, reaching values up to 160 MPa.



Load introduction from metallic dome to cfrp laminate

Demonstrator of the novel hydrogen tank

Partners

- *Daimler Truck AG*
- *Commercial Vehicle Cluster – Nutzfahrzeug GmbH*
- *comlet Verteilte Systeme GmbH*
- *HYDAC Process Technology GmbH*
- *Institut für Oberflächen- und Schichtanalytik GmbH*
- *Thomas Magnete GmbH*

Supported by:
Federal Ministry of Transport and Digital Infrastructure
on the basis of a decision by the German Bundestag

The project "WaVe" is funded by the Federal Ministry of Economic and Climate Action on the basis of a decision by the German Bundestag (funding reference 19I21028K).

Partner

H2Flex – Process and Plant Development for the Production of Geometrically Flexible Hydrogen Pressure Tanks Using a Bio-Based Resin System

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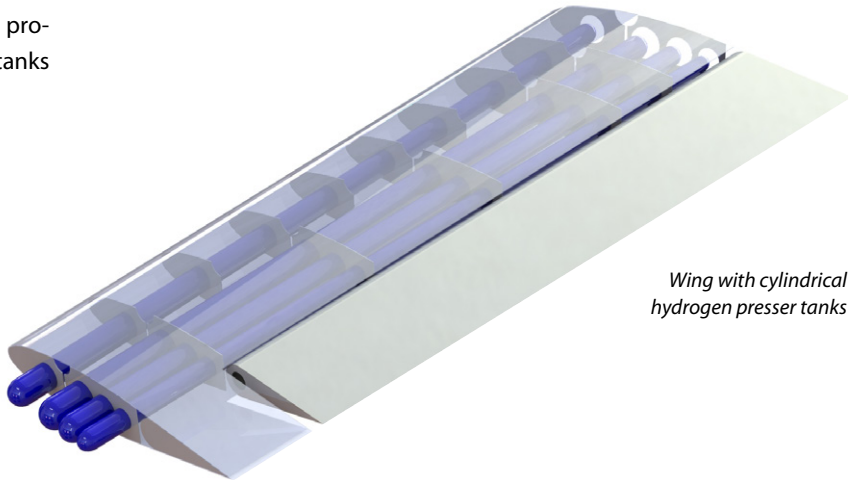
Ulrich Blass

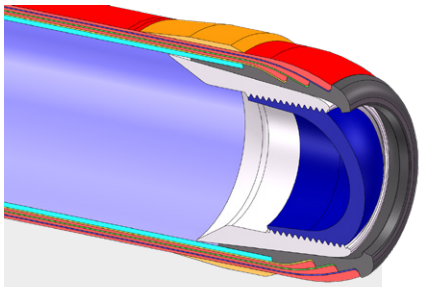
Due to the low volumetric energy density of hydrogen (1.3 kWh/l at 700 bar and 20° C) compared to fossil fuels like gasoline (8.8 kWh/l), optimizing the use of space for hydrogen tanks is essential. However, conventionally wound pressure vessels are very inflexible in terms of their geometric dimensions. Additionally, any change in geometry requires the redesign of the liner (a barrier in the pressure vessel to prevent hydrogen permeation and manufacturing support). Therefore, a new design of cylindrical pressure vessels was developed and patented at IVW, where both the length and diameter can be chosen almost arbitrarily.

Within the framework of the project H2Flex, a manufacturing process is now being developed at IVW to produce the new tank design. Subsequently, in collaboration with the project partner Automation Steeg & Hoffmeyer, a production plant will be designed and built based on this manufacturing process to produce the newly developed pressure tanks automated. In order to improve the environmental impact of the pressure tanks, a bio-based resin system will be used instead of a petroleum-based winding resin. To optimize the resin system for the requirements of the manufacturing process, the project partner Schill + Seilacher will develop a specially tailored bio-based matrix material as part of the project.

In the newly developed tank design, the loads are transfered in the dome area by metallic components. This results in high requirements regarding the tightness and wear behavior in the contact area of the metal parts. To achieve optimal properties for this application, the project partner Karl Wolf Präzision3 will identify suitable materials and surface treatments and manufacture the metallic components accordingly.



Wing with cylindrical hydrogen presser tanks



New developed cylindrical pressure vessels

The project "H2Flex: Process and plant development for the production of geometrically flexible hydrogen pressure tanks using a bio-based resin system" is funded by the Federal Ministry for Economics and Climate Action on the basis of a decision by the German Bundestag (funding reference: 03LB3100A).

Supported by:
Federal Ministry for Economic Affairs and Climate Action
on the basis of a decision by the German Bundestag

Management of Expert Task Force – cFRTP in Automobile Application

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Continuous fiber reinforced thermoplastics (cFRTP) are characterized by their enormous lightweight potential and are predestined for large-scale series (e.g. in the automobile industry) because of their material properties. However, the frequent lack of fully comparable and efficiently calculated material properties are an obstacle for the application of cFRTP in industry.

Against this background, the AVK expert task force "Continuous Fiber Reinforced Thermoplastics" is developing a standardization strategy for cFRTP (organo sheets and tapes) under the direction of the IVW (Picture 1) since its founding in June 2015, focusing on basic parameters for databases. So far, a newly developed tensile specimen geometry as well as a complete test plan are emerged from this strategy. The test plan consistently defines the minimal set of necessary material properties, test conditions and test methods.

Thermoplastic, continuous fiber reinforced high-performance semi-finished products (tapes) offer a high degree of constructive individualization with innovative processing methods.

The determination of characteristic parameters of the tapes, which includes the semi-product-specific measurement of the extreme tensile strength in fiber direction, was successfully carried out using a newly developed ribbon fixture (Figure 1). Through a cooperation with the testing machine manufacturer ZwickRoell, this will be commercially available from 2024. Since the performance of tape tensile tests has not yet been standardized, an ISO standardization is being pursued in this respect. Furthermore, the determination of the interlaminar shear strength in the 5-point bending test as an indicator of the cFRTP processing quality was investigated in the working group and advantages compared to the classic 3-point bending test were identified.

INDUSTRIEVEREINIGUNG VERSTÄRKTE KUNSTSTOFFE
FEDERATION OF REINFORCED PLASTICS

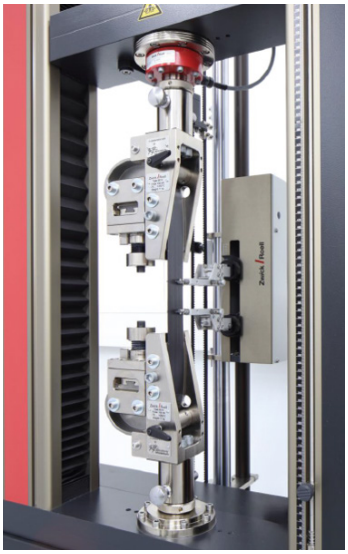
Expert Task Force „Continuous fiber reinforced thermoplastics"

managed by:

Leibniz-Institut für Verbundwerkstoffe

members:

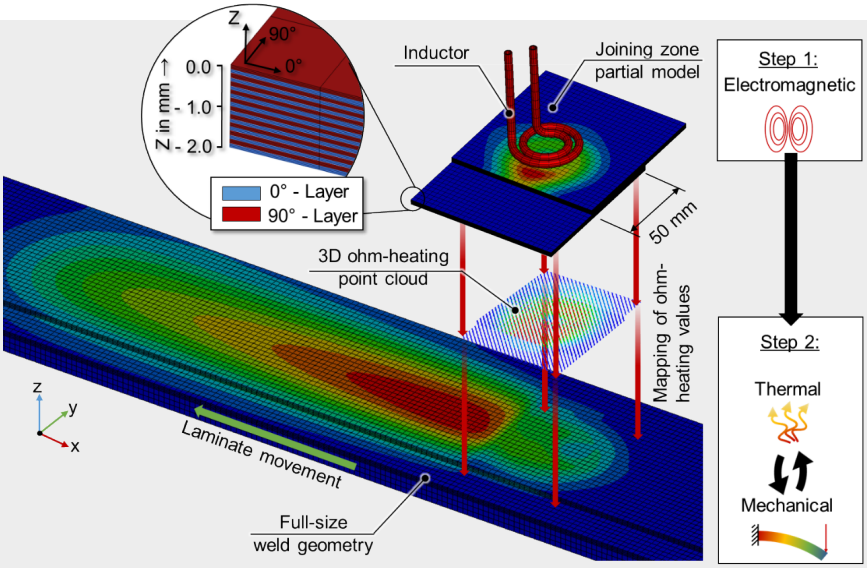
ARKEMA · SOLVAY · Mitsui Chemicals · BOND LAMINATES A company of the LANXESS group · LANXESS Energizing Chemistry · DSM



New tape testing fixture in cooperation with ZwickRoell GmbH & Co. KG

An expert task force managed by IVW and funded by industrial partners works on the efficient, robust and uniform characterization of continuous fiber reinforced thermoplastics and their implementation into standards and material databases.

Efficient Numerical Simulation of Continuous Induction Welding of CFRTP



The decoupled finite element model of the continuous induction welding process using the example of a tensile shear test specimen. The small geometry of the electromagnetic partial model allows the time-efficient use of a high-resolution electromagnetic material model without sacrificing the calculation time of the thermal-mechanical simulation.

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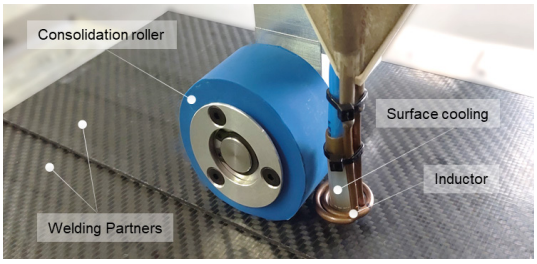
Continuous induction welding is considered to be one of the most promising methods for thermal joining of CFRTP. A major challenge of induction welding is the complex temperature distribution in the joining zone and a lack of efficient and accurate models to calculate the temperature distribution.

In order to establish a basis for the simulation of continuous induction welding, analytical as well as numerical models for the description of the static heating behavior of CFRP laminates were created and extensively validated in previous project phases. On this basis, a simulation model for the induction welding process has been developed in the final phase of the project. By contrast to conventional coupled multiphysics simulations, the electro-magnetic calculation of the heating pattern is performed only once in an upstream simulation. The resulting heating pattern is then integrated as a boundary condition into a thermal-mechanical simulation of the induction welding process. The developed simulation approach was comprehensively validated by means of induction welding experiments. The simulation model has proven to be capable of accurately predicting the temperature distribution in the joining partners. In contrast to previous models, the decoupled calculation method – which for the first time allows the efficient use of high-resolution material models even for large welding geometries – is able to calculate the influence of different laminate layups on the temperature distribution. Planned next steps include not only the simulation of complex demonstrators with several welding paths, but also the coupling of the simulation to an in-situ process control.

The long-term objective is to increase the process speed of the continuous induction welding process of CFRP organo sheets in connection with a resulting joining quality at autoclave level.



The specimens being used for the validation of the simulation model are welded by means of the induction welding robot of IVW.

The project "Process Optimization of Induction Welding of Continuous Carbon-Fiber Reinforced Thermoplastics by Process Simulation" is funded by Deutsche Forschungsgemeinschaft (DFG) (272768988).

DFG Deutsche Forschungsgemeinschaft

Durobast – Durable and Resource-Saving Bast Fiber Reinforced Composite Components

Maximilian Salmins
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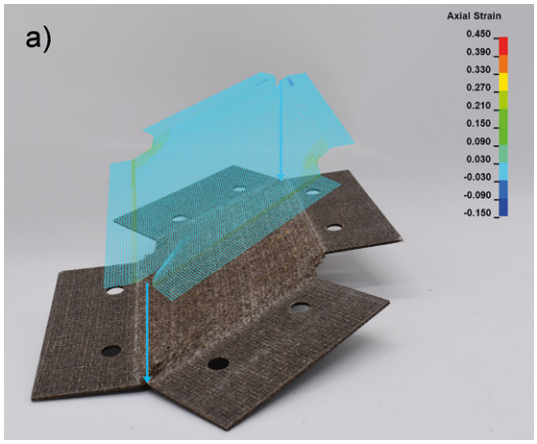
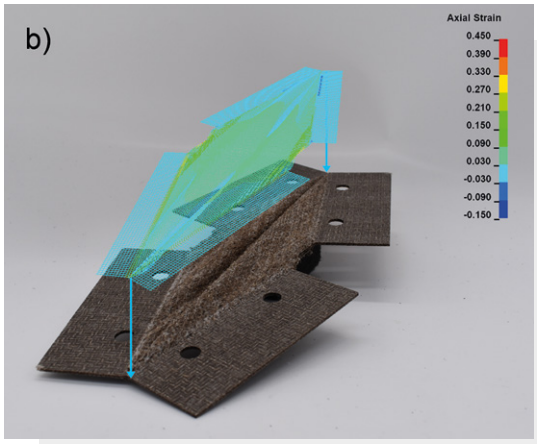




Comparison between the draping behavior of experiment and simulation for shear angles of a) 35° and b) 60°

The use of natural fibers holds great potential for the sustainable and resource-saving design of structural components. As regionally available raw materials, bast fibers such as hemp and flax fibers not only provide an energy-efficient alternative to conventional glass or carbon fibers, but also contribute to a reduced CO_2 footprint through optimized transport routes. The production of fiber reinforced polymer composites (FPR) with bio-based polymers, e.g. polylactic acid (PLA), enables the future-oriented production of structural natural FPR components, which also takes recycling at the end of the product life cycle into account.

The Durobast project covers the entire process chain, from the selection of suitable natural fibers to component production by manufacturers. A particular focus is on fiber pre-treatment by cavity polymerization, which is intended to reduce moisture absorption.

The Leibniz-Institut für Verbundwerkstoffe investigates the manufacturing of natural fiber reinforced organo sheets and the processing of these flat semi-finished products into final part geometries through thermoforming. It is of paramount importance in these processes to minimize the thermal influence on the fibers. Draping behavior is investigated in a shear frame test setup. A finite element model is created based on the results of these tests to determine the process design and to allow part manufacturing at minimal temperatures, while simultaneously minimizing stresses within the reinforcement textile to prevent draping defects of part distortion.

The project Durobasts pursues a holistic approach to the manufacture natural fiber reinforced composites by combining pretreated natural fibers and bio-based polymers to enable future-oriented production.

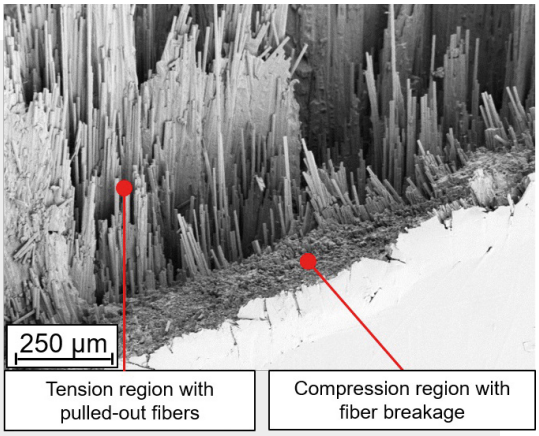
Partners

- *DST Dräxlmaier Systemtechnik GmbH*
- *Eta Ressourcenmanagement*
- *Fraunhofer LBF*
- *Gustav Gerster GmbH & Co. KG*
- *Institut für Textiltechnik (ITA) der RWTH Aachen*
- *Lehrstuhl für Werkstoffprüftechnik (WPT) der Technischen Universität Dortmund*
- *nova-Institut GmbH*
- *Rhenoflex GmbH*
- *Silbaerg GmbH*
- *Wagenfelder Spinnereien GmbH*

Federal Ministry of Food and Agriculture

The project Durobast is funded by the Federal Ministry of Food and Agriculture on the basis of a decision by the German Bundestag (funding reference: 2220NR090C).

Analysis of the Pseudo-Plastic Deformation Behavior of Staple Fiber Organo Sheets



SEM image of a 3-point bending specimen after failure with clear transition between tensile and compressive loaded area

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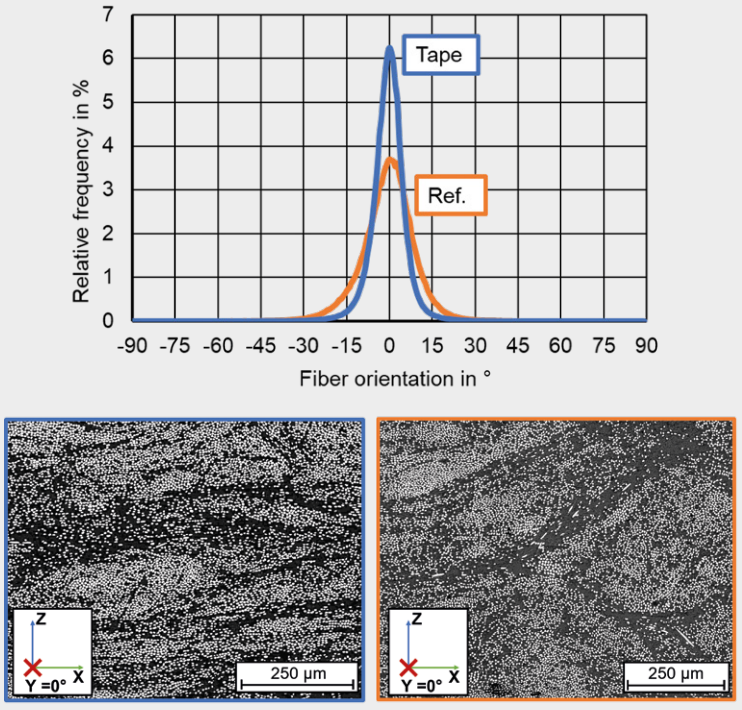
Martin Detzel

This DFG funded project investigates the processing of staple fiber yarns made from recycled carbon fibers (rCF-SF) to organo sheets and the characterization of their pseudo-plastic deformation behavior in thermo-forming experiments.

In the first project phase, rCF-SF consisting of rCF and PA6 were processed into staple fiber tapes (SF tapes) by using a modified calendaring process being developed at IVW. In the calendering unit, the SF yarns are heated above the polymer's melting temperature and stretched by a speed difference between the preconsolidation rolls and the consolidation rolls, thereby improving fiber orientation. The influence of total stretching, temperature and number of machine passes on the tape geometry, the resulting fiber orientation and the mechanical properties were investigated to determine optimum process parameters. During further work, additional stretching will be applied to the SF-tape in the tapelaying process. The resulting impact on fiber orientation and mechanical properties will be quantified subsequently. In the second project phase, SF organo sheets will be tested in temperature controlled tensile tests to evaluate their pseudo-plastic deformation behavior. For this purpose, a test module will be developed to reconsolidate it after finalizing the tensile test. To determine the influences on pseudoplastic deformation behavior, parameters such as process speed, tempera-ture and SF-tape total stretching are analyzed. Based on these findings, a description model for the thermoforming process behavior will be calibrated and subsequently validated. The project goal is to develop an innovative process chain from staple fiber yarn to the finished component. At the same time, a comprehensive understanding for the pseudo-plastic deformation behavior during thermoforming needs to be established.



Analysis of the fiber orientation distribution of the reference sheet wound from the staple fiber yarn and a tape-laid sheet

The project "Process analysis of the pseudo-plastic deformation behavior of unidirectional reinforced staple fiber organo sheets" is funded by German Research Foundation (DFG) – funding reference 471480678.

Translucent Colorable and Flame-Resistant SMC for Aerospace Applications

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In the aviation sector, ecologically beneficial material solutions are becoming increasingly important with respect to high awareness and relevance of climate change. In the passenger cabin, the focus is on both ecological and efficient lightweight construction. Due to the very high design freedom in combination with economical manufacturing costs and efficient production processes, combined with avoiding environmentally harmful phenolic resins at the same time, Sheet Molding Compounds (SMC) offer a high potential for application in the cabin sector. To date, polyester or vinyl ester based SMC semi-finished products with particulate flame-retardants have mainly been used in the cabin sector to meet the strict fire protection requirements (FST = Fire, Smoke, Toxicity). However, this requires very high contents of filler, which have a negative effect on the optical quality of the components (e.g. formation of streaks, not colorable) as well as on the achievable mechanical properties and the required high semi-finished product densities. This significantly limits the possible utilization for current SMCs in aircraft cabins. Most applications in visible components demand post-processing with a cost-intensive and environmentally harmful additional coating due to the poor optical quality. In addition, current SMC semi-finished products are exclusively opaque. In the joint project "TraNa", novel flame-retardant and at the same time translucent or homogeneously colorable SMC formulations are developed for the application in aircraft cabins. An epoxy resin system is used as matrix. The fire protection requirements should be fulfilled by a combination of conventional particulate and liquid fire retardant additives, as well as newly developed Layered Double Hydroxides (LDH) nanoparticles.

SMC Trolley table with paint finish

Photo: Comprisetec

Partners

- *CompriseTec GmbH*
- *Fraunhofer-Gesellschaft e.V.*
  - *Fraunhofer-Institut für angewandte Polymerforschung IAP*
  - *Fraunhofer Institut für Silicatforschung ISC*
- *Schmidt & Heinzmann GmbH & Co. KG*

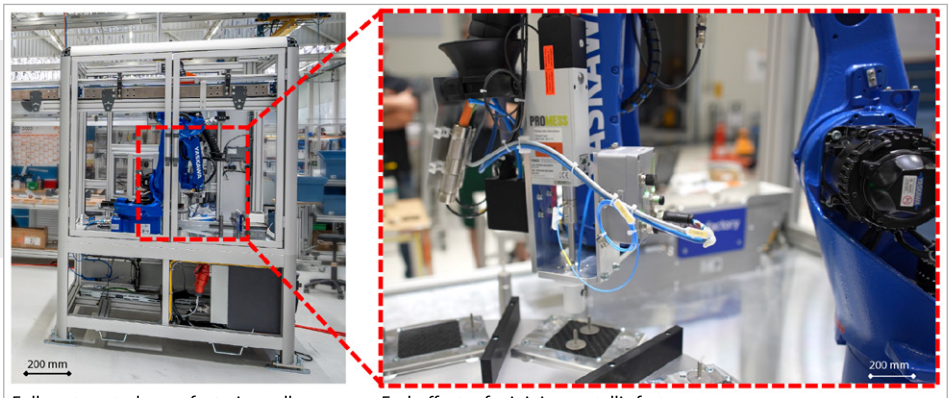
Translucent and flame retardant SMC plate with LDH filler material (paper with imprint behind SMC plate)

Supported by:
Federal Ministry for Economic Affairs and Climate Action
on the basis of a decision by the German Bundestag

The project "TraNa – Translucent colourable and flame-resistant Sheet Molding Compounds for aerospace applications" was funded by the Federal Ministry for Economic Affairs and Climate Action on the basis of a decision by the German Bundestag (funding reference 20Q1902C).

HyBe – Automated Joining of Metal Fasteners to Thermoplastic Composites

HyBe process demonstrator in industrial environment



Fully automated manufacturing cell

End-effector for joining metallic fastener

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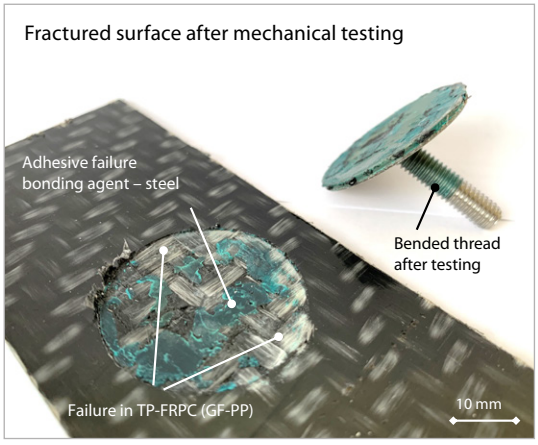
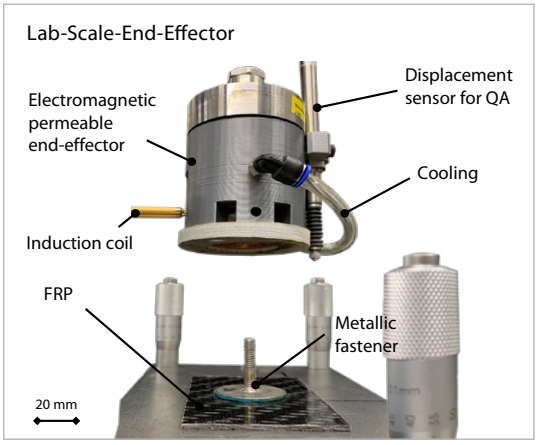
Joints between metal and thermoplastic fiber-reinforced polymer composites (TP-FRP) are highly relevant in many applications in industry, mobility and sports. In order to efficiently utilize the inherent material properties of these materials, advanced joining techniques and optimized joining approaches are required. Geometrically optimized fasteners are particularly suitable for introducing forces homogeneously and over a large area. To ensure the material bonding to the TP-FRP, the fasteners are coated with functional bonding agents. In contrast to techniques such as drilling or clinching, material-to-material thermal joining allows bonding without fiber damage. A threaded connection on the fastening elements is used to integrate the TP-FRP lightweight structure containing the thermally joined fastening elements into a higher-level assembly.

The fastening elements are connected to the TP-FRP structure within a few seconds by inductive joining in a fully automated process environment. Very good strength is achieved, as indicated by cohesive failure in the TP-FRP by trying to detach the fasteners at room temperature. In addition to process development on a laboratory scale, the aim of the IVW work is to achieve optimization of strength and corrosion resistance characteristics through comprehensive parameter analysis. It should be particularly emphasized, that the fasteners can be easily detached from the TP-FRP by heating above the melting temperature of the thermoplastic and reattached, if required. This is particularly advantageous for recycling and repair.

At the end of the project, a technology further developed from the laboratory scale will be implemented in a fully automated production cell for the time-efficient joining of metal fasteners to TP-FRP.

Fracture zone of a mechanically tested fastener joined with a TP-FRP





Partners

- *Kömmerling Chemische Fabrik GmbH*
- *Himmelwerk, Hoch- und Mittelfrequenz-anlagen GmbH*
- *MiniTec GmbH & Co.KG*

The project "Automated hybrid welding of metal fasteners to fiber-reinforced polymer composites (HyBe)" was funded by the ZIM program of the German Federal Ministry for Economic Affairs and Climate Action (BMWK), (funding reference: KK5003706FF1).

Supported by:
Federal Ministry for Economic Affairs and Climate Action
on the basis of a decision by the German Bundestag

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Sonja Adler

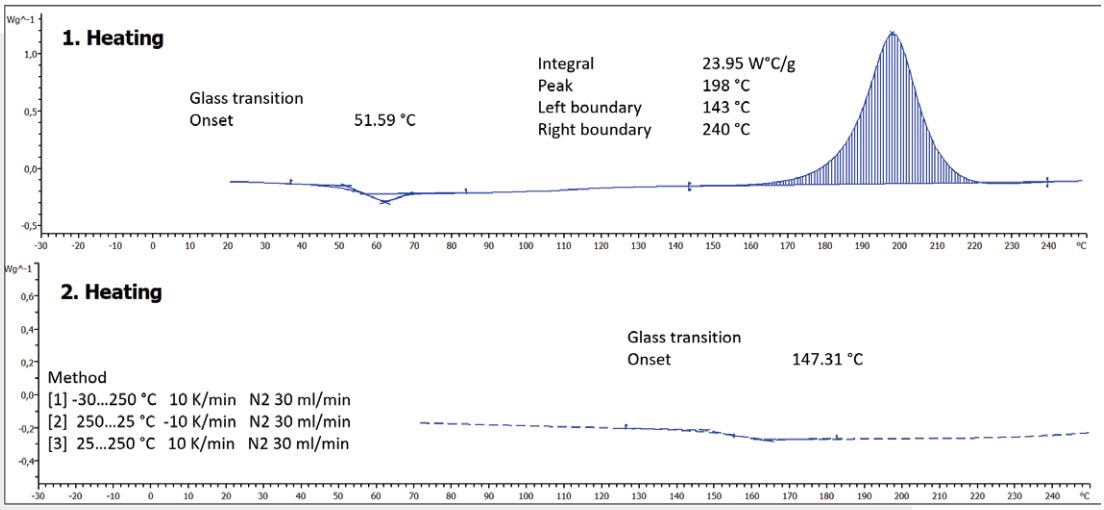
Partner

SMC Semi-Finished Materials for Structural High-Temperature Applications Based on rCF

SMC cladding component with rib

Carbon fiber reinforced polymers (CFRP) play a key role in many industries with lightweight construction requirements. This applies primarily to aviation and automotive technology, but increasingly also to the leisure and sports sector. In addition to pure lightweight construction and the well-known economic challenges, ecological lightweight construction with the demands for sustainable solutions and recyclable materials has increasingly come into focus over the last few years. This goal can only be achieved by consistently pursuing a holistic circular economy for fiber-reinforced polymer materials (FRP) in general and for carbon fiber-reinforced plastics (CFRP) in particular. Therefore, in the „NeuRecA" joint project, targeted material development for reuse in new CFRPC applications is taking place both for carbon fiber production waste (off-cuts from CF textiles and residual coils) as well as for recycled and processed carbon fibers obtained from the pyrolysis of end-of-life (EoL) components. This can significantly reduce the environmental footprint of carbon fiber reinforced components and further increase the attractiveness of the material. Sheet Molding Compound (SMC) is used for the production and processing of semi-finished products, as it allows a high degree of design freedom combined with economical and efficient manufacturing processes. The combination of a newly developed resin paste formulation (based on a high-T_g epoxy resin) and carbon fiber staple yarns lead to the development of SMC semi-finished products, which can be used in structural areas that are subject to high thermal loads.

In the joint project "NeuRecA", novel and innovative SMC formulations based on recycled carbon fibers and epoxy resins will be developed for the use in structural areas for high-temperature applications. This represents a first important milestone towards sustainable CFRP composites.



DSC-measurement results of newly developed high temperature SMC resin paste

Supported by:
Federal Ministry for Economic Affairs and Climate Action
on the basis of a decision by the German Bundestag

The project "NeuRecA – Material and process development for novel SMC semi-finished products based on recycled carbon fibers for structural high-temperature applications" is funded by the Federal Ministry for Economic Affairs and Climate Action on the basis of a decision by the German Bundestag (funding reference KK5003707EB1)

Partner THERME GROUP | Fügetechnik AWOK

Technology Study on the Use of Bio-Based Plastics in the Structural Building Sector

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Alexander Nuhn

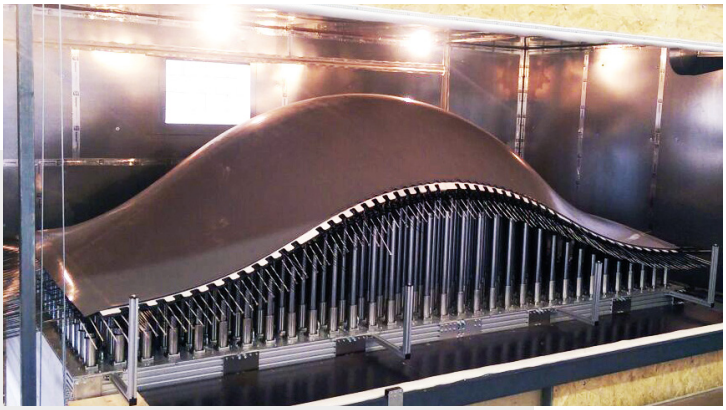
Therme Group, as a designer, builder and operator of thermal facilities worldwide, pursues the primary goal of intensifying "Well-Being" in its facilities. This is to be achieved through the use of innovative materials, methods and technologies to enable the experience of nature in a safe environment, while meeting strict sustainability criteria.

Therefore, Therme Group commissioned together with the Department of Joining Technology / Materials and Surface Engineering Working Group (AWOK) to conduct a technology study on the application of new materials and processes in thermal spas.

The study focused on three main tasks:

1. The in-depth research of polymers and fibers that can be obtained from renewable raw materials and are suitable for the intended application
2. The identification of suitable processing techniques for these materials
3. The consideration and adaptation to building code requirements to ensure the safety and conformity of the planned innovations

The Project goal is the evaluation of an economical yet sustainable method to produce organio structures that can be used under conditions of elevated humidity and heat.



Thermoforming with adaptive mold from Adapa company, approx. 3.6 x 1.5 m

"Vulcan" 3D printed pavilion (Source: Archdaily)

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Light & Sustainable – New Equipment for Thermoplastic Foam Injection Molding

Thomas Neumeyer

Production cell for injection molding of thermoplastic lightweight structures – to be equipped with foam injection molding capability

In the interest of minimizing the use of resources, the importance of manufacturing foamed components in large quantities at reproducible quality is continuously increasing in the context of polymer processing. Thermoplastic foam injection molding is one way of producing foamed structures in the injection molding process. This technology offers both component-specific advantages, such as lower density, less material usage, higher specific bending stiffness and lower warpage, as well as process-specific advantages, such as reduced melt viscosity, lower cavity pressures and therefore lower clamping forces, and the elimination of holding pressure. Components foamed by injection molding are generally recyclable.

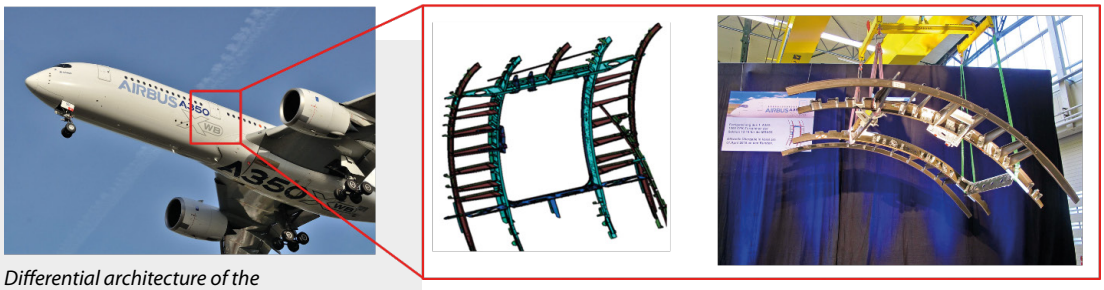
In addition, thermoplastic foam injection molding can also be used for the highly automated production of thermoplastic sandwich structures. In this process, consolidated face sheets with thermoplastic matrix – if necessary preformed – are heated and inserted into the injection mold. The gas loaded melt is subsequently injected between these cover layers and foamed, creating the foam core "in-situ".

As part of a grant for research infrastructure from the state of Rhineland-Palatinate, the existing injection molding technology at IVW is being expanded for thermoplastic foam injection molding. For this purpose, the existing injection molding machine with a clamping force of 400 tons will be equipped with a special plasticizing unit and connected to a gas metering station. In addition, a suitable experimental mold with integrated sensor technology will be designed. All process variables relevant to foam injection molding can thereby be recorded in the production cell and evaluated for use in process and component development.

With this project, the research infrastructure of IVW is expanded by a promising technology for production of sustainable lightweight parts.

The project „Granting the funding of injection molding equipment for physical foam injection molding within the program 'Additional Equipment for Top Researchers'" is funded by the Rhineland-Palatinate Ministry of Science and Health.

LuFo-ZEUS – Zero Emission Aircraft with Sustainable Fuselage Concept and Technology



Differential architecture of the A350 door surround structure

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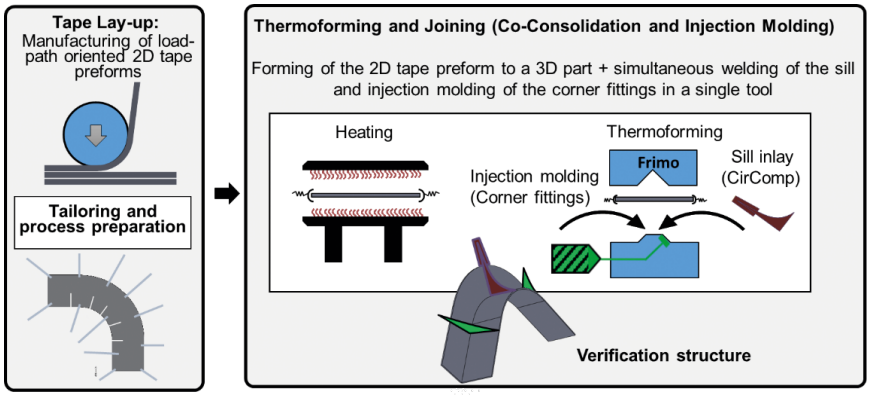
Fiber-reinforced thermoplastic composites (TP-FRP) have many advantages over thermoset materials, including weldability and recyclability. They are therefore gaining increasing interest in the aerospace industry. As part of the LuFo project ZEUS, IVW is investigating the opportunities and challenges arising from the use of TP-FRP for aircraft structures. The feasibility of this field of application is being investigated by studying complex component designs and geometries. a new type of thermoplastic door frame structure and stringer profiles. The main task is the development of a closed process chain, supported by process simulation. IVW pursues a holistic approach that combines design concepts, simulation methods and manufacturing processes for thermoplastic fuselage components.

The process combines tape laying, thermoforming, co-consolidation and overmolding. In addition to process simulation, topology optimization for the design is also used to optimize the results and determine suitable processing conditions. Furthermore, it is possible to combine simulations and real-time data acquisition to create digital twins of the manufactured parts and thus reduce processing trials.

The results then make it possible to predict the quality of the final part, as all relevant processing and material parameters are stored and analyzed.

The developed processing chain enables the application of local reinforcements and thickness changes in profiles by utilizing the bonding possibilities of thermoplastics.

The aim of this project is the development of thermoplastic structural components and suitable process technologies for high-performance aircraft structures as well as the digitalization of the process chain for quality prediction, forecasting and assurance.



Process chain for manufacturing complex parts

Partners

- *Airbus Aerostructures GmbH*
- *Airbus Operations GmbH*
- *CirComp GmbH*
- *Deutsches Zentrum für Luft- und Raumfahrt e.V.*
- *Fraunhofer-Gesellschaft e.V.*
- *FRIMO GmbH*
- *XELIS GmbH*

The project "LuFo-ZEUS – Zero Emission Aircraft with Sustainable Fuselage Concept and Technology" is funded by the Federal Ministry for Economic Affairs and Climate Action on the basis of a decision by the German Bundestag (funding reference 20W2106F).

Supported by:

Federal Ministry for Economic Affairs and Climate Action

on the basis of a decision by the German Bundestag

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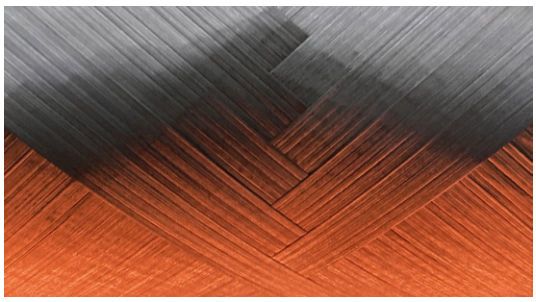
Partner

MaTaInH2 – Material-Efficient and Cycle-Time Optimized Industrialization of H2 Pressure Tanks

Benedikt Bergmann



Mobility concepts with locally emission-free engine systems are undoubtedly one of the main drivers of the automotive industry of the future. In this era of growing environmental awareness and the need to reduce greenhouse gas emissions, the search for efficient and environmentally friendly mobility options occupies a central place in the research and development of automotive manufacturers. In this respect, hydrogen is proving to be a promising alternative to the battery electric vehicles already available. The use of hydrogen as an energy carrier in mobile applications offers the perspective of significant advantages in terms of range and speed of refueling. A key aspect of realizing this technology is the pressurized tank, which must be able to store sufficient hydrogen under an operating pressure of 700 bar. At the same time, these tanks must be light enough to meet the requirements of mobile applications.

The research project "MaTaInH$_2$ – Material-efficient and cycle-time-optimized industrialization of H$_2$ pressure tanks" pursued the goal of creating a competitive alternative to the current state of the art by using pre-impregnated fiber rovings, so-called towpregs. This project involved the new development of a Type-IV hydrogen pressure tank, which were designed from scratch and manufactured using a winding process. The special feature of this collaborative projectlay in the possibility of optimizing the individual process steps independently of each other by dividing the production chain into sub-processes. IVW plays a crucial role in this project, both in characterizing the reference materials and the newly developed towpreg from the department of carbon composites of the Technical University of Munich (TUM) and in optimizing the winding process. A comprehensive material map was created that summarizes all relevant mechanical and process-related properties.

To meet the requirements of a near-series winding process, the existing winding line at IVW was further improved for the processing of towpreg semifinished products. The findings from the production of prototype pressure tanks made from towpregs are being incorporated into the specification of an optimized industrial-scale winding equipment.

In the course of the project, the production of almost 50 pressure tanks using conventional wet winding and towpreg winding created a broad database on the material behavior and processability of towpregs as well as the general production of hydrogen pressure tanks. The results from the winding tests and the burst tests showed the potential of the chosen holistic approach and the improvement of material and process quality. The cyclic endurance tests in accordance with the UN ECE R134 standard were also successfully carried out to ensure the fatigue strength of the tanks.

In the "MaTaInH$_2$" research project, the project partners MAHLE, TUM and IVW were pursuing the objective of developing and evaluating the entire process chain of towpreg development under aspects suitable for large-scale production and deriving industrialization concepts from this.

Pressure Vessel-Towpreg-Laminte heated by infrared radiation

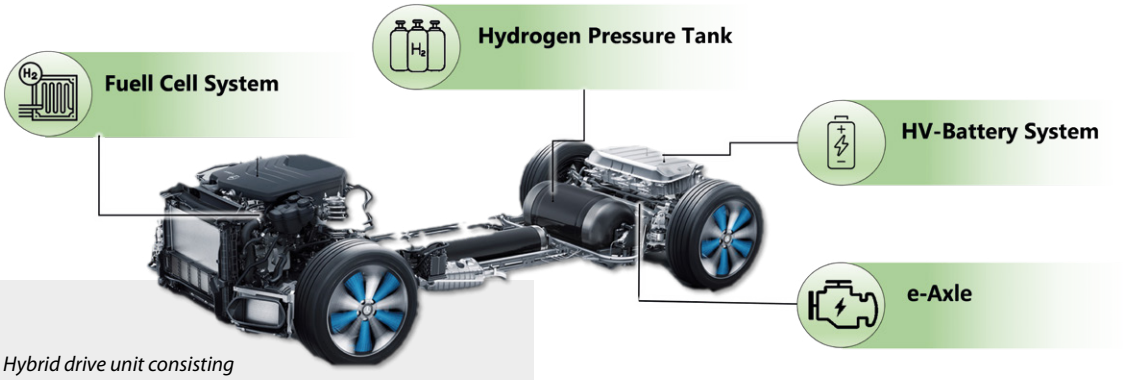
Modified winding head for Towpreg winding

Installation position of pressurized hydrogen vessels in the Toyota Mirai

Beauftragt durch: Bundesministerium für Verkehr und digitale Infrastruktur
Vergabe und Projektbegleitung durch: NOW-GMBH.DE, PTJ Projektträger Jülich Forschungszentrum Jülich

The project was funded by the Federal Ministry of Transport and Infrastructure (BMVI) as part of the program "National Innovation Program Hydrogen and Fuel Cell Technology Phase 2 (NIP II)".

DigiTain – Digitalization for Sustainability



Hybrid drive unit consisting of fuel cell and HV battery system
© Mercedes-Benz GLC F-Cell (2018)

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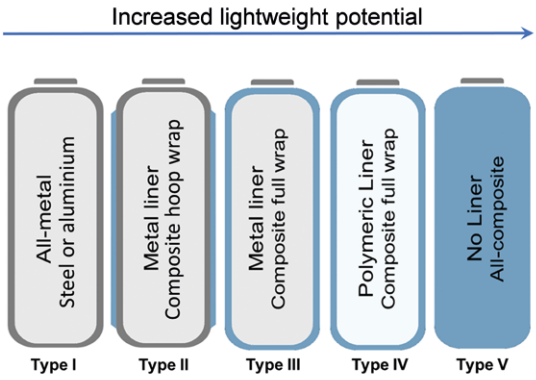
The increasingly present climate change underlines the importance of technical developments related to sustainability. In the transport sector, electric drives offer great potential for sustainable mobility, especially when combined with fuel cells and hydrogen tanks. In order to emphasize sustainability aspects, a sustainability-oriented development process (SDP) for fully digital product development is being elaborated in the project "DigiTain – Digitalization for Sustainability". The project involves 27 other partners from industry and research.

To apply and validate the SDP, a vehicle with a hybrid drive concept (fuel cell with HV battery system) is being developed. One key element is the hydrogen pressure vessel. So-called Type-IV tanks (CFRP with internal plastic liner) enable the required high pressures due to the low volume-related energy density of gaseous hydrogen at room temperature and fulfill lightweight construction requirements. They represent a classic field of application for fiber reinforced polymer composites.

Together with our partners, IVW optimizes and enhances a special direct towpreg winding process for the production of Type-IV tanks. Objectives are increasing the efficiency and sustainability of the process and transitioning it from the current laboratory scale to industrial readiness. Process digitalization ensures data acquisition for digital twins to be used for process optimization and quality assurance. Innovative material technologies, that promise improved properties and resource efficiency, will also be investigated. These include „thin-ply"-materials, whose suitability for the production of Type-V tanks is being evaluated.

In the project "DigiTain", IVW and its partners will develop an innovative winding process for the production of H2 pressure vessels to industrial maturity. There will be a digitalization to optimize the process as well as the quality of the pressure vessels.



Pressure vessel types
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Supported by:
Federal Ministry for Economic Affairs and Climate Action
on the basis of a decision by the German Bundestag

The project „DigiTain – Digitalization for Sustainability" is funded by the Federal Ministry for Economic Affairs and Climate Action on the basis of a decision by the German Bundestag (funding reference 19S22006P).

ML4ProcessSimulation – Machine Learning for Process Simulation

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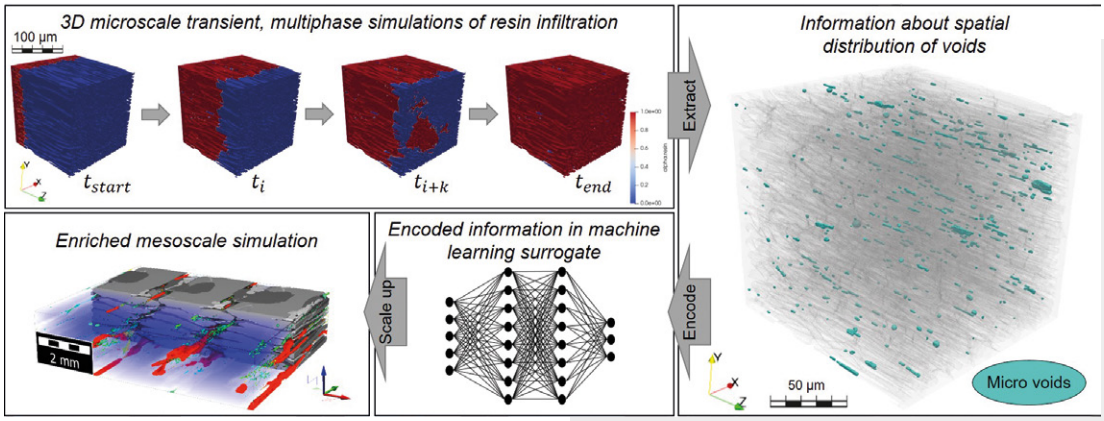

Illustration of the 3D microscale transient resin infiltration simulation of a fibrous microstructure (fiber level) and the machine learning assissted scale up of the void formation information from the micro- to the mesoscale (fiber to textile level).

Multi-scale approaches are used to reduce the computational effort for the simulation of fiber-reinforced polymer composites (FRP). For example, impregnation is simulated separately at the fiber, textile and component levels, and data is exchanged between the scale levels. As with any simulation, various simplifications are made, such as neglecting capillary forces and homogenizing local properties when transferring to the higher level. In the "ML4ProcessSimulation" project, the integration of machine learning methods is intended to increase the accuracy and efficiency of the simulation workflows.

So far, numerical simulation methods (including finite volume and Lattice-Boltzmann methods) have been investigated for the efficient generation of training data. Permeability prediction could achieve comparable accuracies to experiment at the fiber level using neural networks (NN). In addition to feed forward NNs that require characteristic values as input, 3D convolutional NNs that use geometry models as input were investigated. These NNs can be integrated to efficiently predict local micropermeability at the textile level. Further research focused on the integration of physical laws in model training (physics-informed neural network) and transient simulations of multiphase flows, which allow the integration of further physical effects. This method can be used to estimate air pockets in the fiber structure, which typically represent mechanical weak points in the FRP.

The goal of the project is to integrate machine learning methods into multiscale simulation approaches to efficiently account for relevant physical effects for accurate simulation of resin injection processes.

Project consortium for ML4ProcessSimulation

gefördert durch Leibniz-Wettbewerb

The project „ML4ProcessSimulation – Machine Learning for Simulation Intelligence in Composite Process Design" is funded by the Leibniz Association within the Leibniz Collaborative Excellence funding programme (funding reference: K377/2021)

Partner Fraunhofer ITWM

Process Digitalization of Carbon Fiber Reinforced Sheet Molding Compounds (C-SMC)

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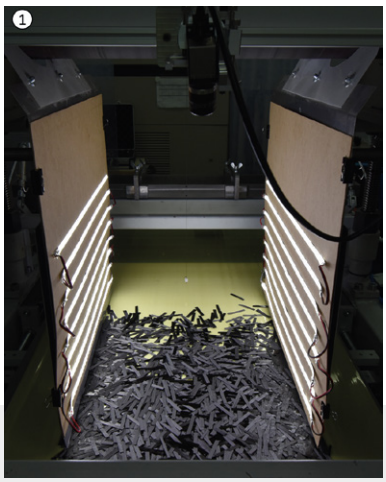
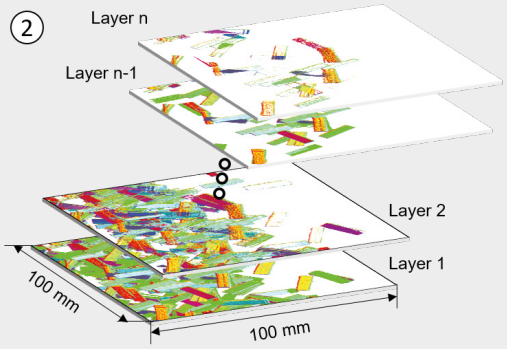
Dominic Schommer

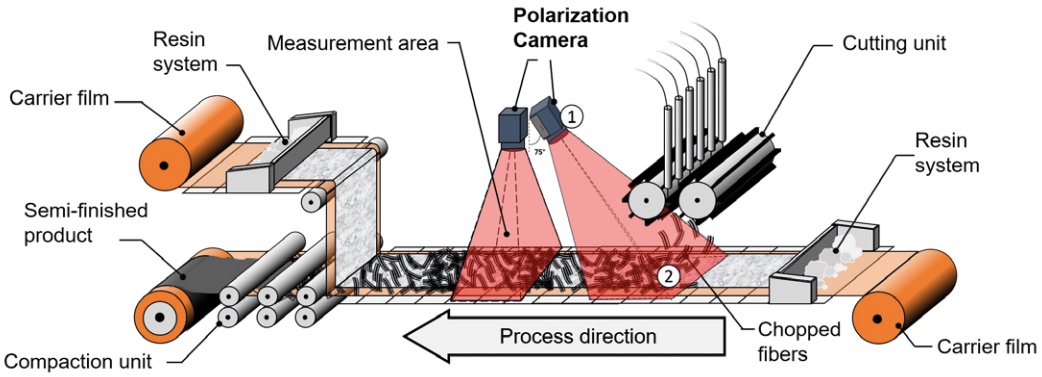
To develop a better understanding of the material behavior of carbon fiber reinforced sheet molding compounds (C-SMC) during processing and thus improve the prediction of the structural properties of a finished part, knowledge regarding the constituent material interactions is essential. For this reason, this research project combines experimental and virtual tests to investigate the structure and properties of a C-SMC semi-finished product. Special attention is given to the investigation of fiber orientation, length and content as well as the interaction between the fibers and resin. By exploiting the polarizing effect of carbon fibers when incident light is reflected from their surfaces, localized fiber orientation can be captured in real time by a compact polarization camera. The camera is integrated directly into the SMC production line, where it is used to detect the fiber distribution and overall material anisotropy in the resulting C-SMC semi-finished product. Positioning the camera near the cutting unit of the equipment allows direct recording of the formation of the material's fiber structure as a sequence of 2D images. In a subsequent digitization process, the image stack is converted into a complete three-dimensional image of the fiber structure in a complete roll of semi-finished product. Once the real material and its digital twin are available, experimental and virtual testing can be performed simultaneously. This includes press rheometer tests to characterize the behavior of the C-SMC material during the compression molding process and an investigation of the resulting fiber behavior as well as permeability tests to analyze the resin flow through the fiber reinforcement to draw conclusions about the possible fiber-resin separation behavior.





1. *In-situ measurement of fiber orientation during C-SMC manufacturing by polarization imaging*

2. *3D layer-wise digital twin of C-SMC semi-finished product*



Schematic of machine vision based 3D-digitalization of fiber orientation by means of a polarization camera in a C-SMC production line

This project is being carried out in close collaboration with the Flow and Material Simulation Department of the Fraunhofer Institute for Industrial Mathematics (ITWM) within the framework of the High Performance Center Simulation and Software Based Innovation.

HIGH PERFORMANCE CENTER SIMULATION- AND SOFTWARE-BASED INNOVATION

Partner cmt swiss composite materials & technologies | GREENBOATS

MarineCare – Sustainable Composites for Marine Applications

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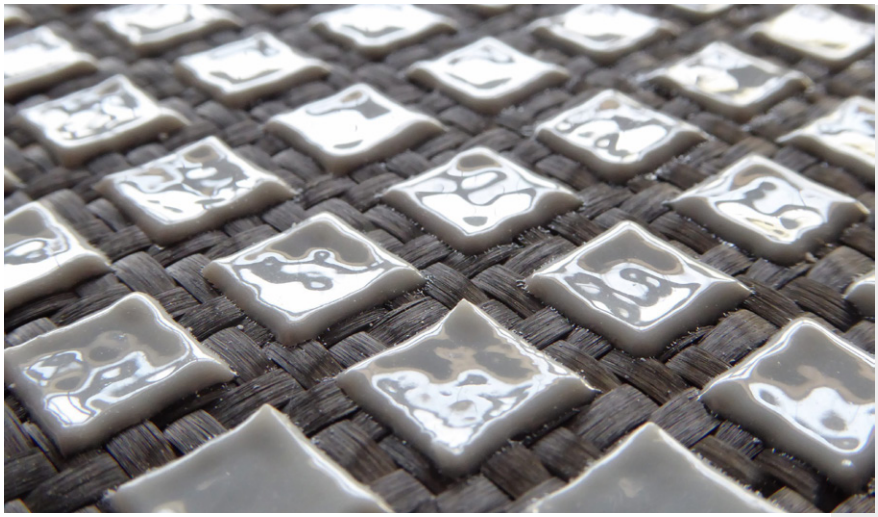
The aim of the project was the development of a sustainable sandwich composite material with a core made of cork or recycled PET, prepreg face sheets made of recycled carbon fibers (rCF) and a bio-based solid epoxy resin. By using a solid resin, it was possible to replace the classic vacuum infusion process with a more resource-efficient process variant that requires significantly fewer auxiliary materials. Crucial for this was the development of prepregs at IVW. For these, the textiles were not impregnated – as usual – over the entire surface, but in a pattern form.

The pattern impregnation improves the evacuation behavior of the prepregs and allows draping at room temperature. Within the scope of the project, the influence of various pattern and process parameters on processability and achievable laminate quality were investigated. The results were published in the Polymer Composites Journal (https://doi.org/10.1002/pc.27696). In cooperation with the project partners Swiss CMT AG and GREENBOATS GmbH, a demonstrator in the form of a foil board was manufactured by using the newly developed material and process technologies.

Sustainable composite sandwich material with unidirectional rCF top layers and a cork core, right: unidirectional rCF-textile



Manufactured solid resin prepreg with a squared pattern

SPONSORED BY THE
Federal Ministry of Education and Research

The Eurostars project „MarineCare – Sustainable Composites from Recycled Carbon Fiber and Bio-based Powder Resin for Marine Applications" was funded by the Federal Ministry of Education and Research on the basis of a decision by the German Bundestag (funding reference 01QE2028C).

KI4MaterialModeling – AI-based Object Detection in Computed Tomography Data

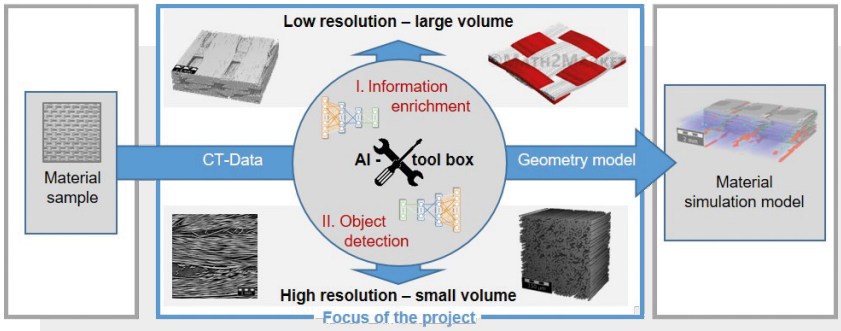


Illustration of the intended workflow from the material sample to the "computable" material simulation model with the two AI tools to be developed for information enrichment and object detection

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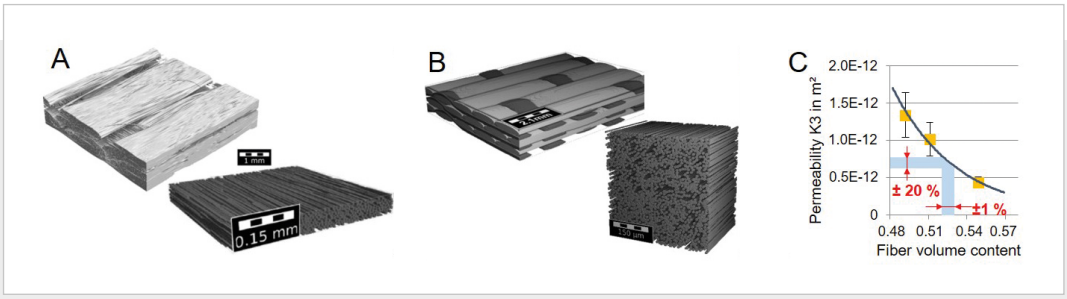
Simulations have become an indispensable part of modern material development, predicting properties by mapping material structures. Digital models are essential in simulation chains, but precise separation of material phases on different length scales is crucial for accurate property simulations. Current methods involve computed tomography CT scans and computer-generated models, both with limitations leading to deviations in simulations. In CT scans there is always a trade-off between resolution and the field of view (size of the scanned volume) and unavoidable image artefacts lead to the fact that the segmentation of the material phases is subject to uncertainty. The computer-generated models require a high number of parameters for precise modeling, whereby the aforementioned challenges (especially uncertainty in the extraction of geometric dimensions) remain.

In KI4MaterialModeling, together with the Math2-Market, the gap between the two mentioned methods shall be closed by using artificial intelligence (AI) methods. The AI-based workflow comprises: (1) generation of synthetic CT data to train AI, (2) AI for enhancing the trade-off between sample size and resolution in CT scans, (3) AI for object recognition in CT data. This workflow improves materials analysis and development efficiency.

Applications include:

- Supporting segmentation and object recognition in real CT data to arrive at high-quality geometry model
- Automated extraction of structural information from CT data for synthetic model generation
- Combining CT data with synthetic data to create a hybrid model with large volume at high resolution

The aim of the project is to close the gap between synthetically generated geometry models and geometry models derived from CT data through the systematic use of AI methods.



(A) CT scan of a tissue structure and a fiber bundle section, computer-generated "replicas" (B) and diagram showing the dependence of tissue permeability on fiber volume fraction (C)

The project "KI4MaterialModeling: Development of an AI-based workflow for object recognition in computed tomography data using the example of fiber reinforced plastic composites" is funded by the German Federal Ministry of Education and Research (funding code: 01IS23054B).

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Equal Opportunities at IVW

Both pictures show congratulations on parenthood

For the 2nd time, IVW has been awarded the "TOTAL E-QUALITY" certification, acknowledging its exemplary commitment to equal opportunity-oriented personnel management. This accolade, bestowed annually by the German association, underscores the institute's steadfast dedication to fostering equal opportunities for both genders in the workplace, particularly in leadership roles. This includes promoting work-life balance, fair recruitment practices, and inclusive workplace behavior – all integrated into the company's core values.

During the inaugural "IVW Female Recruiting Day", nine accomplished female Master's students and graduates from various universities gathered to explore potential careers as scientists at IVW. The event began with insightful presentations on cutting-edge topics such as shape-shifting fiber composite structures, composite applications in implants and orthoses, and renewable bio-composites, followed by a guided laboratory tour. In the tranquil setting of the Kaiserslautern garden show and during a shared dinner, fruitful discussions arose about work conditions, career advancement, dissertation opportunities, extracurricular activities, and the institute's social environment.

Furthermore, IVW actively participated in STEM outreach. Our researcher, Nithya, provided a virtual glimpse into composite materials research for students in grades 5-10 on BMBF's Girls' Day 2023 in collaboration with the VDI Technology Center. During the Virtual Lab Day 2023, our researcher, Sonja, presented an overview of IVW's materials research and discussed methods for material failure analysis. At the "MI(N)TMACHWELT" event at the Gartenschau in Kaiserslautern, IVW researchers led a workshop on lightweight materials, showcasing unique properties and applications of composites.

To cap off the year, at IVW's Christmas party, we welcomed our staff's newborns and congratulated this year's recipient of the gender equality award. For additional details, please visit our website's "Equality & Equal Opportunities" section.

Further information can be found on our website under the "Equality & Equal Opportunities" section.

Staff

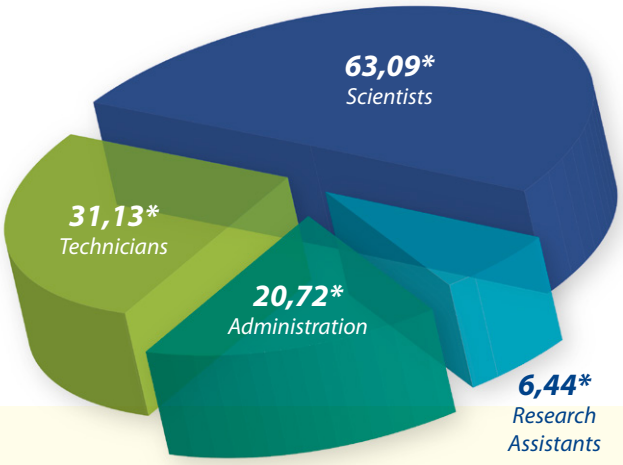
In 2023, an average of 121 dedicated employees (FTE) were responsible for outstanding and innovative work, combined with a great deal of scientific knowledge and experience, which again generated valuable research results. They were actively supported by 31 student and research assistants.

Our scientific guests, doctoral students, interns and students in the context of study, diploma, bachelor and master theses also made an important contribution to our research and devel-opment work.

Around 250 people from 27 nations were active in a wide variety of positions at the institute this year. The proportion of foreign scientists was around 25%.

Women accounted for around 26% of the staff on average over the year, and around 19% of the scientific staff.

We are happy for Björn Willenbacher, Stefan Weidmann and Max Kaiser for successfully completing their doctorates this year.



** Number of full-time equivalents*

Congratulations!

Max Kaiser

Stefan Weidmann

Björn Willenbacher

IN ADDITION

PhD students	2
Guest scientists	10
Students (theses)	76
Trainees	7

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EXIST Transfer of Research

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Knowledge & Technology Transfer (KTT)

Our goal is the transfer of knowledge and technology to business, science and society – and we are pursuing various transfer paths to achieve this.

Spin-offs

- *We proactively support spin-offs*
- *We promote Exist projects – from application to implementation*

Contract research

- *We find the right solution for industrial R&D challenges*
- *We are active in all important networks to connect you with the right partner*

Property rights

- *We foster the culture of innovation*
- *We promote inventions – from the idea to the industrial property right*

Standardization

- *In the interest of users, we advocate the right standards*
- *IVW experts are active in national and international working groups for standardization*

Transfer through heads

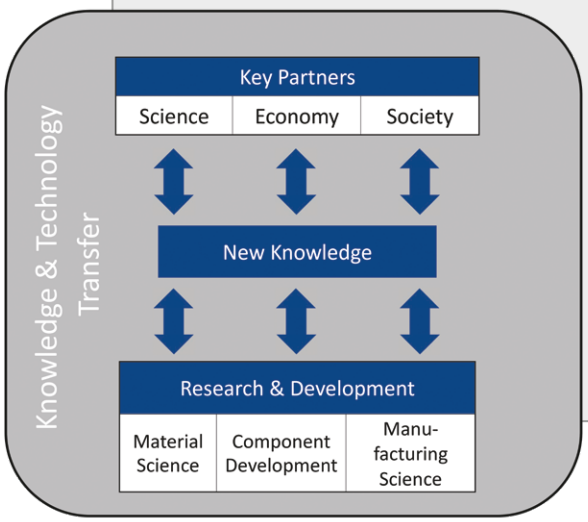
- *Technology is in the mind: We organize the right technical seminars for you*
- *We educate: Our graduates are bearers of advanced technology*

Infrastructure services

- *You are looking for support, e.g. in materials testing or structural testing – we can help you*
- *You want to break new ground in production technology – we have the equipment for you*

Science communication

- *We are active at trade fairs and in networks*
- *We impart knowledge: To school students, citizens, science, industry and politics*



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Regional Division CU West of Composites United e.V.

The CU West cluster aims to make a decisive contribution to strengthening regional competencies in the field of high-performance fiber composite technology. Together with IVW, future technologies are being developed in the following working groups:

- Thermo-plastics – from material to automated production
- Smart Structures – multifunctional composites
- Composite Fatigue
- Bio Composites
- Orthopedic Technology

In the monthly "Jour Fixe", CU members briefly introduce themselves and then discuss a central topic from their technology field with the participants under expert guidance, while the "Composites meet User Industries" series takes place quarterly. Guests are welcome.

CU West is one of the seven regional clusters in Composites United e.V., the world's largest network for fiber-based multi-material lightweight construction with 350 members. CU West has 60 members in western Germany – a number of highly innovative SMEs, renowned large companies and international research institutions.

Dr. Heinz Kolz *Managing Director CU West*
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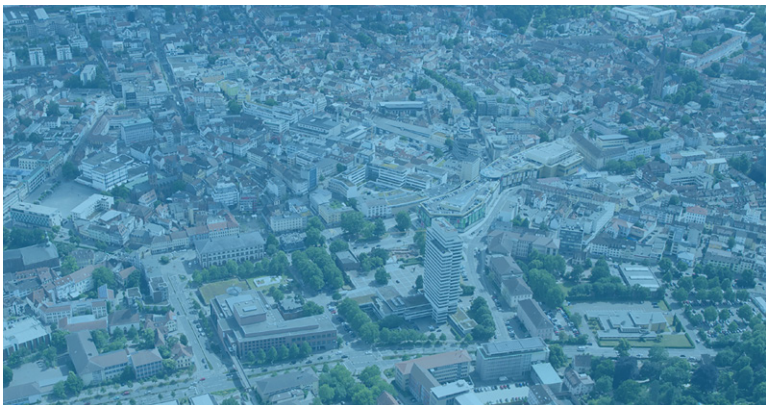
Science & Innovation Alliance Kaiserslautern e.V.

Science and Innovation Alliance Kaiserslautern e.V. (SIAK) is a non-profit association based in Kaiserslautern.

SIAK brings together the region's scientific and technical expertise and innovative business skills and connects them to initiate and catalyze successful projects, collaborations and business relationships. SIAK aims to strengthen the positioning of Kaiserslautern and ist surroundings as a leading location in science and innovation on a regional, national and international level.

Our network is characterized by the high level of commitment of our members and network partners as well as an efficient organization.



For further information on current projects and contacts at SIAK, please visit www.siak-kl.com.

Current Cooperations

We are part of a global network of internationally leading composite research institutions.
Through strong cooperation in international projects, exchange of world-class experts and our "on site" presence we have access to leading-edge technology and latest composite knowledge.

IVW expressly acknowledges the high importance of international exchange, both for the professional qualification of individuals and for the scientific quality of research at IVW.

On this account, IVW is sending scientists and scholars every year to research institutions abroad and at the same time affording outstanding foreign guest scientists research stays at IVW. The exchange is promoted at the level of established researchers as well as the level of young scientists in order to enhance the development of the Institute and its staff in many ways:

- Qualification of young scientists
- Expansion of the international research network
- Joint projects with international partners
- Promotion of intercultural cooperation

This is accomplished through national and international funding opportunities such as those of the Alexander von Humboldt Foundation (AvH), the German Academic Exchange Service, the German Research Foundation, and foreign programmes such as the Marie Curie Fellowships (EU) or the Chinese Scholarship Council. In this way, more than 100 exchanges have been enabled since 2010.


Scotland
University of Edinburgh
England
• National Composites Centre, Bristol
• National Physical Laboratory, Teddington
• University of Nottingham
• University of Sheffield
Sweden
• Luleå University of Technology
• RISE Research Institutes of Sweden AB
Leibniz-Institut für Verbundwerkstoffe
Netherlands
Delft University of Technology
Belgium
Katholieke Universiteit Leuven
Ukraine
National Acadamy of Sciences of Ukraine, Kyiv
Austria
• University of Leoben
• Johannes Kepler University Linz
France
IMT Mines Alès
Slovenia
University of Ljubljana, Faculty of Mechanical Engineering
Greece
University of Ioannina
Switzerland
ETH Zurich
Luxembourg
• Luxembourg Institute of Science and Technology
• University of Luxembourg
Italy
• Polytechnic University of Milan
• Institute for Polymers, Composites and Biomaterials, Catania
Spain
• Technical University of Catalonia, Barcelona
• University of A Coruña
• University of Jaén
Portugal
CeNTI / CITEVE, Vila Nova de Famalicao
Australia
University of Sydney
New Zealand
University of Auckland

International Cooperation

VolkswagenStiftung

Through a grant from the Volkswagen Foundation, IVW was able to offer two Ukrainian scientists, who had to leave their country due to the war, an opportunity for further scientific development. Dr. Maryna Novitska and Prof. Nataliia Hudzenko (both from the National Academy of Sciences of Ukraine (Kiev), joined the IVW team from June 2022 til May 2023 and worked in the two subprojects "Machine Learning for Flow Simulation – Crossing the Borders Between Civil and Materials Engineering" and "Bio-Based Non-Isocyanate and Phosgene-Free Polyurethanes" to significantly support ongoing work at IVW and to further advance interdisciplinary research.

Prof. Nataliia Hudzenko and Dr. Maryna Novitska

We would like to thank the Volkswagen Foundation for its support.

Andreas Baumann visited Texas A&M University (USA) as part of the effort for a better understanding of the interrelation between matrix polymer and the composites fatigue properties. The visit took place in autumn 2023. With the aim of improving, the material model for polymers under fatigue loading the work benefited from Prof. Anastasia Muliana's experience in time dependent material modelling. In the discussion and based on the experimental results gathered so far, ideas where developed on how to improve the modelling of the polymer with special focus on fatigue. The idea to relate morphological changes on a sub-fiber level to the observed property changes was identified as promising approach for gathering insights into the damage onset on a fiber-matrix level.

We would like to thank Texas A&M University for the fruitful cooperation.

Automation Steeg & Hoffmeyer GmbH

Dr.-Ing.
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Chief Executive Officer

For more than 50 years the Automation und Steeg Hoffmeyer GmbH represents solutions in special engineering. A core task of the foundation in 1972 was to find efficient and automated technology solutions. Since this time Automation Steeg und Hoffmeyer GmbH has been a reliable and competent partner for the production of semi- and fully automated machinery for the glass and pharmaceutical industry. As quality proof we are proud to announce that much of our equipment is still in use and some machines have been operating for more than three decades. Since 2010, we have established the new business field for fiber reinforced composites. The old goals and core competencies will be retained in automation technology. We deliver customized system solutions, and we build special machines for the automated production of high-quality fiber reinforced composite structures.

www.automation-gmbh.com

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A+ Composites GmbH

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Chief Executive Officer

A+ Composites, established in 2015 through the EXIST Research Transfer Program, operates at the forefront of technological advancement in composite materials. Specializing in the production of UD tapes, the company's core competency lies in developing and manufacturing tapes predominantly composed of carbon or glass fibers infused with polyolefins, polyamides or polyesters. The company regularly processes other plastics, specialty fibers, and blends according to customer specifications.

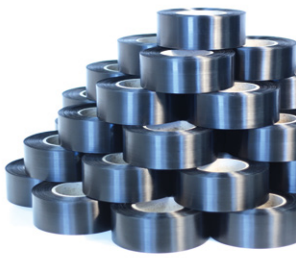
With a commitment to innovation, A+ Composites has produced over 250 distinct UD tapes since its inception. The company holds numerous patents and has received several awards, showcasing its dedication to pushing the boundaries of composite material possibilities. In addition to production, A+ Composites also actively engages in research projects.

Strategic partnerships play a central role in the company's success, with alliances formed across suppliers, customers and universities, creating a collaborative network.

A+ Composites' competencies extend beyond UD tape production to include the fabrication of preforms, precision slitting of UD tapes and the production of injection molding inserts and binder tapes.

The company revolves around innovation, collaboration and a persistent pursuit of excellence, contributing to the ongoing evolution of composite materials and their applications across industries worldwide.

www.aplus-composites.de



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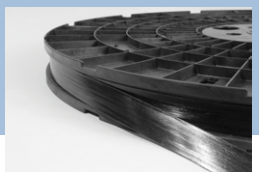
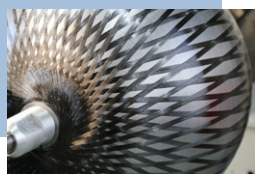
CirComp GmbH

Dr. Ralph Funck
Senior Director R & T

CirComp GmbH is specialized in the manufacturing of components from composite materials in filament winding technology. Furthermore, processing of continuous fiber reinforced thermoplastic tapes is developed and used for cost-efficient production with short cycle times like injection molding or pressforming. By specific combination of different fibers and matrix materials and the use of special reinforcement architectures, the products become tailor-made components of composite materials for different applications and requirements. CirComp GmbH is a guarantor for the reliable supply of high quality products and is leading manufacturer for advanced lightweight and cost-efficient components. CirComp GmbH is a subsidiary of Albany Engineered Composites (AEC) since November 2019. AEC acts at the leading edge of 3D-Weaving Technology followed by high rate RTM and closed molding for Aerospace Application.

www.circomp.de





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CompActive GmbH

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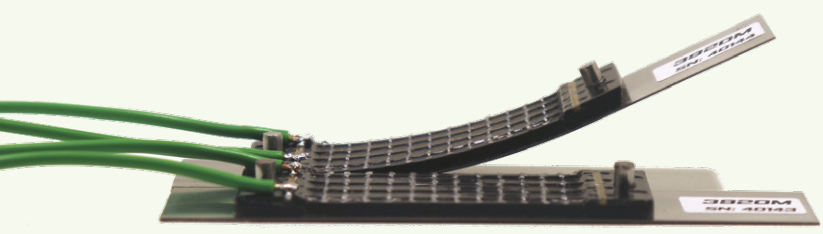
CompActive is a young technology company focusing on the development and production of actuators – more specifically novel bending actuators. The patented technology allows the special performance profile of shape memory alloy to be used economically while keeping system complexity low. This means that conventionally required components such as mechanics, motor and gearbox are no longer needed. By integrating the active modules into products, desired adjustment functions are possible in the most compact installation space with minimal additional mass. Whether it's an innovative functional enhancement or a new version of an established adjustment function, CompActive offers everything from feasibility studies and the construction of functional prototypes to detailed design and manufacturing, all the way from the idea to the new series product. The recently established manufacturing facility in Neustadt an der Weinstraße ensures quality and availability "Made in Germany".

www.compactive.de



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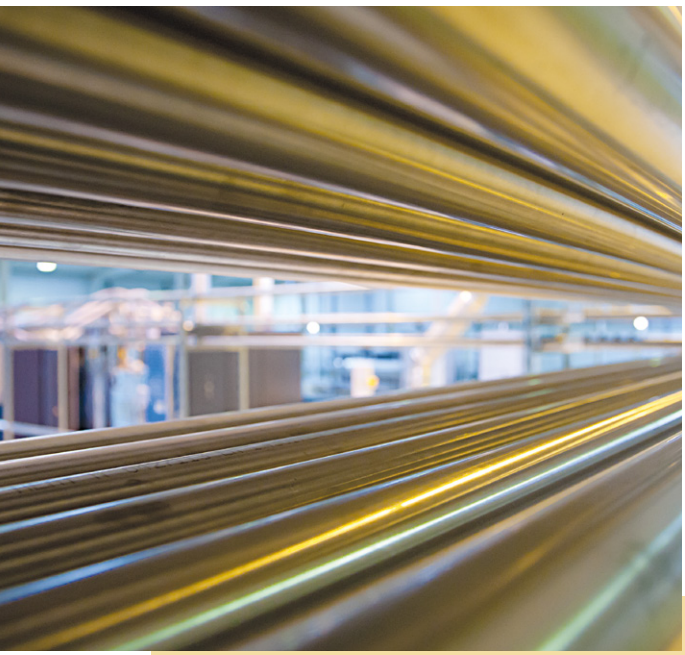

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Easicomp GmbH was founded in 2011 and is a leading service provider in the field of LFRT (long fiber-reinforced thermoplastics). Easicomp´s services include, amongst others, counseling, production, development and distribution of thermoplastic composites. The Easicomp team, consisting of qualified and experienced experts in LFRT, can therefore offer its clients "the whole package" around the subject "thermoplastic composites". Current projects address the topics of re- and up-cycling as well as antimicrobial functionality in LFT compounds.

www.easicomp.de

Success made „easi"!

Easicomp GmbH
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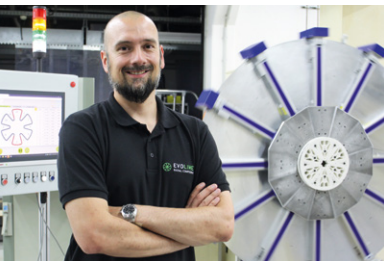
Evolime GmbH



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Chief Executive Officer

The current processes for manufacturing wheel structures from fiber-reinforced polymer composites (FRPC) are often not very flexible or require a high degree of manual working steps, making their use uneconomical for many areas of application. The founders of Evolime GmbH have brought an alternative manufacturing technology to market stage. The publicly funded technology development "CompoSpoke" is based on a wet winding process in which fibers are automatically wound onto small molded parts and simultaneously formed into wheel structures. The process is currently the only fully variable process for the production of monolithic composite wheel structures from a single continuous fiber. It is virtually free of waste and therefore has a very good environmental balance. Combined with mold construction using 3D printing, it enables efficient and flexible production of spoked wheels made of carbon and other fiber polymer composites alike. The use of the technology aims primarily at markets in mechanical and plant engineering as well as mobility applications.

www.evolime.de

The "CompoSpoke" project is funded by the German Federal Ministry for Economic Affairs and Climate Action and the European Social Fund as part of the EXIST program.

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INTELLIGHT

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Owner & CEO

INTELLIGHT stands for unique competence and more than 20 years of experience in the analysis of potentials, the development and implementation of intelligent plastic, composite and hybrid lightweight construction solutions in almost all industrial sectors.

INTELLIGHT is completely independent in terms of materials and processes: We offer objective expert advice to identify the potentials of lightweight construction solutions in the respective field of application. Based on state-of-the-art engineering methods with computer-aided design and state-of-the-art simulation techniques, we implement lightweight construction solutions tailored to our customers' needs, from the first functional prototype and component testing right up to series production.
www.intellight.de

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Gründungsbüro RPTU & HS Kaiserslautern

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Manager
Gründungsbüro

The „Gründungsbüro" (start-up office) started in 2008 as a competent contact point for all those members of the University of Kaiserslautern and the University of Applied Sciences Kaiserslautern-Landau interested in establishing their own company. Our mission is to embed entrepreneurial spirit and leadership competence in the everyday academic and research practice. The objective of our measures is to increase the number of spin-offs, particularly in the technology sector.

It all starts with raising awareness and qualification for entrepreneurial thinking and acting. Individual consultancy and a broad supply of workshops teach important entrepreneurial core competencies. This helps to develop young leadership personalities, create a supportive environment and strengthen the entrepreneurial spirit.

Students, alumni, scientists and all other staff members of the two universities and research institutes receive professional support tailored to their particular needs and topics. We want to encourage all people to realize their ideas by starting their own business.
www.gruendungsbuero.info

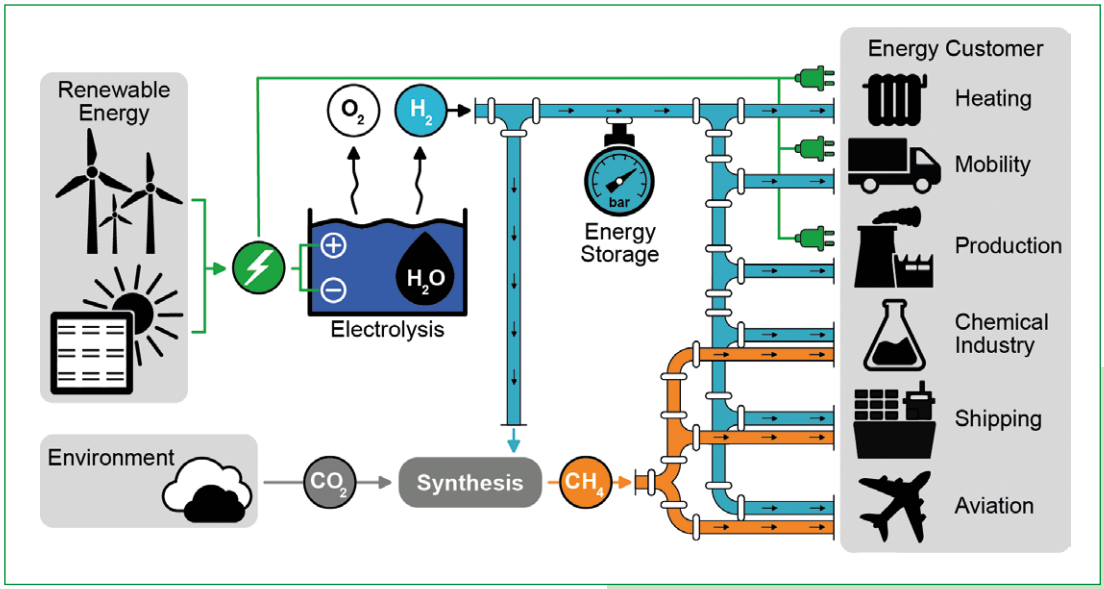
Participants of
"Highway to Hightech" at IVW

Gründungsbüro der RPTU & HS Kaiserslautern
Postfach 3049 | 67653 Kaiserslautern | info@gruendungsbuero.info

NEW

Isitec-Composites

isitec composites



Climate-neutral energy management based on renewable energies with hydrogen as a key element for coupling different industrial sectors

Dr.-Ing.
Tobias Donhauser
Project Manager

The development of a sustainable, global energy system based on renewable energies requires a system for coupling all sectors of energy consumption. Green hydrogen, which is generated in a climate-neutral manner from renewable electricity, is a versatile energy carrier and is ideally suited for this. For the practical implementation of a functioning energy economy based on green hydrogen, storage and pipeline transport systems are necessary. Such pipelines are nowadays exclusively made of steel materials. Depending on the operating mode and pressure, they have to be oversized at a high cost, since steel tends to change its mechanical properties when it comes into contact with hydrogen (hydrogen embrittlement). Alternatively, pipelines can be made from fiber-thermoplastic composites. Although these are resistant to hydrogen, they are expensive to manufacture due to the manufacturing methods currently available. Thus, a significant cost advantage compared to steel pipelines is currently not possible. The goal of isitec-composites is to change this. With the help of a new manufacturing process, high-performance pipelines for transporting hydrogen can be manufactured inexpensively from fiber-thermoplastic composites. The basis is a direct impregnation process that enables the processing of raw materials, consisting of fibers and thermoplastic polymer, directly into the finished hydrogen pipe. As a result, intermediate steps of conventional manufacturing methods are avoided, which can lead to a significant cost advantage. The new technology thus offers the opportunity to accelerate the establishment of a climate-neutral, hydrogen-based energy industry by reducing investment costs.

eXIST Existenzgründungen aus der Wissenschaft
Supported by: Federal Ministry for Economic Affairs and Climate Action on the basis of a decision by the German Bundestag
EUROPÄISCHE UNION
ESF Europäischer Sozialfonds für Deutschland
Zusammen. Zukunft. Gestalten.

Leibniz-Institut für Verbundwerkstoffe GmbH
isitec composites | 67663 Kaiserslautern | tobias.donhauser@leibniz-ivw.de

IVW Student Competition: Congenial Composite Carrier

The solutions of a tricky task were put to the final challenge in the competition: From a few given materials, including glass and carbon fiber fabric with synthetic resin, a means of transport had to be designed, calculated, built and tested in a period of a few months, which transported a full can of cola over a distance of 40 m undamaged and in the shortest possible time. Electrochemical drives were not permitted, nor were CO_2-generating drives. An cost limit of 50 euros for additional materials was not to be exceeded.

Fiber-reinforced tube constructions working with positive and negative pressure, 3-D printed chassis constructions made of polylactic acid plastics with an ingenious rubber traction system, designs working according to the gondola principle and a particularly impressive trebuchet, a special form of catapult with a weight and whip system, were used. Fiber composite constructions and braking mechanisms ensured not only lightweight designs but also the necessary robustness during acceleration and deceleration or in the event of a possible impact in the target area, as damage to the Coke can would lead to disqualification. Before the competition, all design descriptions and calculations had to be submitted to the jury, and for final permission to start, the teams also had to explain their safety concept. Speeds of over 300 km/h were then measured on the competition track, and (almost) all the Coke cans survived the ultra-fast transport. At the IVW barbecue in the evening, the participants were able to enjoy their certificates and much applause.

For more impressions of our student competition, please scan the QR code

1st Place for Team "KK Solutions"

2nd Place for Team "Weight-Watcher Engineering"

3rd Place for Team "GFK"

Teaching

In 2023, the institute was able to offer 50 semester hours of lectures and laboratories at the University of Kaiserslautern-Landau and the University of Applied Sciences Kaiserslautern with its 3 professors as well as 9 internal and external lecturers. In addition, students gained insights into modern research operations and current, promising research topics by working on student theses. 19 project and student research projects, 4 bachelor theses, 13 master and diploma theses as well as 5 dissertations were completed last year. Colloquia, technology transfer, and internships supplemented IVW's offer in teaching and research. In addition, the institute's employees also contributed to non-university lectures and training, e.g. the biannual fundamental seminar "Thermoplastic Reinforced Composites", organized by CUeV.

RPTU – Rheinland-Pfälzische Technische Universität

Winter Term	SWh
Introduction to Composite Materials May / Breuer / Hausmann / Wetzel	3
Design and Analysis of Composite Materials Hausmann	2
Commercial Aircraft Composite Technology Breuer	2
Joining Technologies for Composites Geiß / Neumeyer	2
Designing with Plastics Endemann	2
Laboratory "Technology of Materials" Eifler / Geiß / Breuer / Mitschang / Seewig	4
Integrated Product Development with Composites May	4
Biomimetics in Materials Science Wetzel	4
Laboratory "CAE with Composite Materials" Duhovic	3
Physica of Polymers Gurka	2

Summer Term	SWh
Processing of Composite Materials Mitschang	2
Design of Composites Schmeer	2
Fatigue and Life Cycles Magin	2
Light Weight Stuctures Hausmann	4
Laboratory "Machine Design" Beck / Eigner / Geiß / Mitschang / Müller / Sauer / Stephan	4
Physics of Multifunctional Materials Gurka	2

Hochschule Kaiserslautern – University of Applied Sciences

Winter Term	SWh
Tribology Gebhard	2
General Chemistry Gryshchuk	4

Summer Term	SWh
Materials from renewable resources and material cycles Gryshchuk	2

Excerpt from our Intellectual Property Rights

- **DE10201310248 6B3**
  Verfahren zur kontinuierlichen Messung des hydro-dynamischen Kompaktierungsverhaltens einer Verstärkungsstruktur
  Becker, David; Rieber, Gunnar; Franz, Holger

- **DE202019102255.8**
  Zylinderauszugskörper zur Prüfung des Adhäsionsvermögens zwischen Kunststoff/Metall-Kunststoff-Hybriden
  Becker, Yves

- **DE102011056637B4**
  Verfahren zur Fertigung eines Kunststoffbauteils
  Brzeski, Markus

- **DE102018113797.4**
  Herstellverfahren und Herstellungsvorrichtung zum Herstellen eines Speichensterns aus einem Endlosfaser-Kunststoff-Verbund sowie Speichenstern und Speichenrad
  Bücker, Marcel

- **DE202020101561.3**
  Vorrichtung zur Konditionierung von Werkstoffen
  Donhauser, Tobias

- **DE102021114985.1**
  Verfahren und Vorrichtung zur Deorbitierung eines künstlichen Satelliten aus der Erdumlaufbahn
  Esha

- **DE102021109854.8**
  Verfahren zur Auslegung und Betriebsvorhersage von trockenlaufenden und mangelgeschmierten Maschinenelementen mit Gleitfunktion
  Fickert, Marc; Gebhard, Andreas

- **DE102018101758.8**
  Vorrichtung zur tribologischen Vorqualifizierung von Filamenten
  Gebhard, Andreas; Brunner, Stefan

- **DE102018110692.0**
  Verfahren und Vorrichtung zur zeitaufgelösten Analyse von Transferfilmen
  Gebhard, Andreas; Jim, Bai-Cheng

- **DE10201510680 2B3**
  Biegeaktuator mit Formgedächtniselement
  Hübler, Moritz; Fritz, Lisa; Nissle, Sebastian; Gurka, Martin

- **DE202018001559.8**
  Gitter aus Formgedächtnislegierung mit einem Kupferanker
  Hübler, Moritz; Gurka, Martin; Nissle, Sebastian

- **DE102012102841B3**
  Verfahren zur Präparation eines Roving
  Lichtner, Jens; Mack, Jens; Steeg, Markus

- **DE102005018477B4**
  Garn mit mineralischen Fasern
  Molnár, Peter

- **DE10200600510 4B3**
  Verfahren zur Überwachung eines Bauteils aus einem Kunststoffmaterial
  Molnár, Peter; Ogale, Amol; Mitschang, Peter

- **DE102015107281.5**
  Faserverbundwerkstoff-Hohlprofilstruktur mit verlorenem Hohlkern
  Motsch, Nicole; Magin, Michael

- **DE112015003290A5**
  Faserverbundwerkstoff-Verbindungsabschnitt und Herstellverfahren
  Pfaff, Thomas; Magin, Michael; Schmitt, Uwe

- **DE102012109671B4**
  Vorrichtung und Verfahren zur Fertigung einer Vorform
  Rieber, Gunnar

- **DE10201100950 6B4**
  Vorrichtung zur Herstellung hohler Formbauteile aus einem Faserverbundwerkstoff
  Rieber, Gunnar; Hummel, David

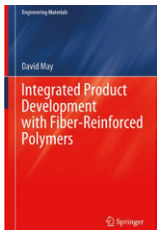
- **DE502013001471.1**
  Deformationselement zur Absorption kinetischer Energie, aus derartigen Elementen hergestellte Einheit sowie Verfahren zur Herstellung eines derartigen Elements
  Schmeer, Sebastian; Schmitt, Uwe; Pfaff, Thomas; Scheliga, David

- **EP 4146460**
  Verwendung eines Faserverbundwerkstoff-Verbindungsabschnitts zur Verbindung einer rohrförmigen Faserverbundwerkstoffstruktur mit einer Anschlusseinrichtung
  Schmitt, Uwe; Pfaff, Thomas; Magin, Michael

- **DE102008009540B3**
  Vorrichtung zum Umformen eines Werkstückes aus einem thermoplastischen Werkstoff
  Velthuis, Rudi

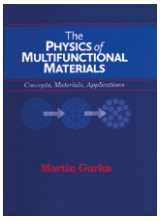
- **DE102005018478B4**
  Vorrichtung zum Induktionsschweißen von Kunststoffteilen
  Velthuis, Rudi; Collet, Christoph

Books by IVW Authors (selection)



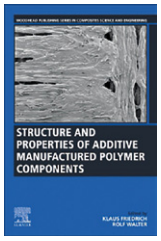
Integrated Product Development with Fiber-Reinforced Polymers
David May
Springer Vieweg, 2021
ISBN: 978-3-030-73406-0

https://www.springer.com/de/book/978030734060



The Physics of Multifunctional Materials: Concepts, Materials, Applications
Martin Gurka
DEStech Publications, 2019
ISBN: 978-1-60595-260-4

https://www.destechpub.com/product/physics-multifunctional-materials/

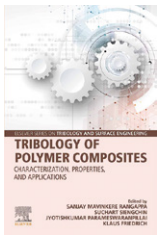


Structure and Properties of Additive Manufactured Polymer Components
Klaus Friedrich, Rolf Walter
Woodhead Publishing, 2020
ISBN: 978-0-12-819535-2

https://www.elsevier.com/books/structure-and-properties-of-additive-manufactured-polymer-components/friedrich/978-0-12-819535-2

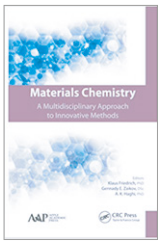
Commercial Aircraft Composite Technology
Ulf Paul Breuer
Springer, 2016
ISBN: 978-3-319-31917-9

https://www.springer.com/de/book/9783319319179



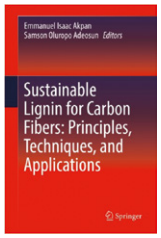
Tribology of Polymer Composites: Characterization, Properties and Applications
Sanjay Mavinkere Rangappa, Suchart Siengchin, Jyotishkumar Parameswaranpillai, Klaus Friedrich (Editors)
Elsevier, 2020
ISBN: 978-0-12-819767-7

https://www.elsevier.com/books/tribology-of-polymer-composites/mavinkere-ragapa/978-0-12-819767-7



Materials Chemistry: A Multidisciplinary Approach to Innovative Methods
Klaus Friedrich, Gennady E. Zaikov, A. K. Haghi (Editors)
Apple Academic Press, 2015
ISBN: 978-1-77188-251-4

https://www.appleacademicpress.com/title.php?id=9781771882514



Sustainable Lignin for Carbon Fibers: Principles, Techniques, and Applications
Emmanuel Akpan,
Samson Oluropo Adeosun (Editors)
Springer, 2019
ISBN: 978-3-030-18792-7

https://www.springer.com/de/book/9783030187910

Multifunctionality of Polymer Composites: Challenges and New Solutions
Klaus Friedrich, Ulf Breuer
Elsevier, 2015
ISBN: 978-0-323-26434-1

https://www.elsevier.com/books/multifunctionality-of-polymer-composites/friedrich/978-0-323-26434-1

Handbuch Verbundwerkstoffe: Werkstoffe, Verarbeitung, Anwendung
Manfred Neitzel, Peter Mitschang, Ulf Breuer
(Hrsg.) Hanser Verlag,
2. aktualisierte und erweiterte Auflage, 2014
ISBN: 978-3-446-43696-1

https://www.hanser-fachbuch.de/buch/Handbuch+Verbundwerkstoffe/9783446436961

JANUARY

Let's get digital!
IVW launches new Program Area "Digitalization"

A new, fourth program area was founded on January 1, 2023, which is to synergistically complement the existing program areas of Component Development, Materials Science and Manufacturing Science. Under the leadership of PD Dr.-Ing. habil. David May, important future areas will be researched in the two competence areas of the program area, "Process Simulation" and "Digitalized Process and Material Development". One focus is on end-to-end simulation chains from fiber to component, led by IVW simulation expert Dr. Miro Duhovic. To realize such multi-scale approaches, upscaling methods between the different scale levels have to be developed as well as experimental methods for input generation and digital models on which the simulation can take place. Another focus is on process data acquisition.

Following the premise of "the right sensor at the right place", holistic concepts are being developed, whereby virtual studies with process simulations make it possible to minimize the data acquisition effort and at the same time maximize the informative value. In order to prepare a targeted use of the data, the program area will also address the basic topic of ontology, i.e. the semantic description of composite materials, processes and simulations as well as their relations. Closely related to this is the issue of data exploitation through data-driven methods that can be used in a variety of ways. In the program area, application scenarios are conceptualized (e.g. property prediction based on process IST data). These form the basis for the design of process data acquisition on the one hand and for the selection and implementation of the most effective machine learning methods on the other hand.

FEBRUARY

Rosenmontags-Science Slam in Cooperation with CU West

The monthly "Jour Fixe" has become an integral part of the networking activities of the CU West cluster of Composites United e. V. Deviating from the usual procedure, the members were offered a very special event on Rosenmontag, the highlight of German carnival. Under the moderation of PD Dr.-Ing. habil. David May from the Leibniz-Institut für Verbundwerkstoffe (IVW), the CU members were offered a very special event: a science slam.

Six scientists from IVW were given the task of presenting their respective field of research not only in a generally understandable way but also as entertainingly as possible in a maximum of seven minutes. A tricky task that all participants solved excellently.

Organizers and participants of the Science Slam (from left to right: David May, Benedikt Boos, Maximilian Salmins, Tim Schmidt, Max Kaiser, Manuel Kunzler, Esha, Heinz Kolz)

APRIL

IVW Female Recruiting Day on April 12, 2023

At the first "Female Recruting Day" of the IVW on 12 April 2023, 9 female Master's students or graduates from different universities informed themselves about the possibilities of working as a scientist at the IVW in the future. After an introduction to the IVW, the programme began with specialist presentations on fibre composite structures that can change their shape at the touch of a button, on the use of composites for implants and orthoses, and on so-called "Biocomposites" that can be made from renewable raw materials, and continued with a tour of the laboratory. female applicants for future job advertisements.

During a walk through the beautiful garden show in Kaiserslautern and also during the joint dinner, there were then many opportunities for mutual exchange to find out about working conditions, development opportunities, dissertation work, joint activities also outside the working world as well as about the social environment. IVW would like to further increase the proportion of women in its scientific staff and is very much looking forward to a larger number of female applicants for future job advertisements.

APRIL

JEC in Paris

JEC World 2023, held in Paris from April 25 – 27, 2023, is the global trade show for composite materials and their applications. It is the industry's leading event, hosting all the major players in a spirit of innovation, business, and networking. The event welcomed more tha 40,200 professional visits from more than 106 countries, attending conferences, product and technology displays from 1,200 exhibitors.

IVW, as a member of Composites United e.V., presented the newest developments of leading edge composites technology like hybrid manufacturing processes and hydrogen storage pressure vessels.

JUNE

"Jugend forscht" State Competition: Third Place for "Mobile Power Plant for Rivers"

At the Rhineland-Palatinate state competition "Jugend forscht 2023", two students from the Heinrich-Heine-Gymnasium Kaiserslautern, Max and Lennox, achieved third place with their project "Mobile Power Plant for Rivers". The project had previously won the regional competition in Landau and was also awarded the special prize "Environmental Technology".

They were supported in the implementation of their idea by IVW employees Christoph Queck and Jannis Hüppauff.

IVW would like to thank the young researchers for their ideas and their drive and hopes to welcome them back as scientists at IVW in a few years.

JULY

ICAF Poster Award for Frances González Ramírez

On June 2023, the International Committee on Aeronautical Fatigue and Structural Integrity (ICAF) held their 38th ICAF Conference and 31st ICAF Symposium. This combined ICAF 2023 event was held from 26-29 June 2023 in Delft, the Netherlands. The IVW in collaboration with the engineering consultant ar engineers participate this year with a Poster presentation entitled "stacking sequence effect on the fatigue behaviour of single lap shear bonded joints". Our Poster was voted "Poster of the Day" by all participants and in the final round of voting among all the day's winners came in a very close second.

Congratulations to the main author Francis Gonzalez Ramirez and our project partners Luiz Lise and Fabian Nowacki from ar engineers!

JULY

Student Competition

The solutions of a tricky task were put to the final challenge in the competition: From a few given materials, including glass and carbon fiber fabric with synthetic resin, a means of transport had to be designed, calculated, built and tested in a period of a few months, which transported a full can of cola over a distance of 40 m undamaged and in the shortest possible time. Electrochemical drives were not permitted, nor were CO_2-generating drives.

More Information on our Student Competition can be found on page 72.

SEPTEMBER

IVW Colloquium

The international IVW Colloquium took place in September 2023 under the motto "Eco-Efficiency with Composites". Over two days, more than 100 participants gained an insight into the latest developments in the field of composites.

The contributions from IVW alternated with user contributions from industry, so that the applications were shown in addition to the basics. The scientific program was rounded off with a visit and guided tour of the Pfalzgalerie in Kaiserslautern.

SEPTEMBER

Farewell Prof. Mitschang

The IVW colloquium was followed by the official farewell to Professor Peter Mitschang.

Professor Mitschang joined the institute in 1996 as group leader of the "Manufacturing Science" department. In 1999, he became Scientific Director of this department, was appointed Honorary Professor in 2003 and was appointed University Professor at the Technical University of Kaiserslautern in 2010. Prior to this, he held various positions in R&D at G.M. PFAFF AG in Kaiserslautern and was most recently responsible for "Technology Development and Technical Calculation" and "Product Pre-Development".

In the laudation, our Supervisory Board Chairwoman Dr. Zimmermann thanked him for the very good and trusting cooperation over many years. Through his commitment, he has significantly shaped IVW. In the second laudation, PD Dr. David May presented the most important key points of his 27 years at the institute. In addition to the outstanding scientific achievements with many supervised doctoral theses, the speech was peppered with many "IVW internals" and anecdotes that showed the humorous person Peter Mitschang is. We wish Peter Mitschang all the best for the future.

SEPTEMBER

Welcome Prof. Neumeyer

Since September 1, 2023, Professor Dr.-Ing. Thomas Neumeyer is the new head of the Program Area Manufacturing Science at IVW, succeeding Professor Mitschang.

Professor Neumeyer, studied precision engineering / mechatronics at the Munich University of Applied Sciences and graduated in 2010. He then worked as a research assistant at the Chair of Polymer Materials at the University of Bayreuth from 2010 and also as head of the Thermosets and Fiber Composites working group there from 2012.

In 2015, he completed his doctorate under Professor Volker Altstädt on the topic of "Structure and properties of new, flame-retardant prepreg matrix systems for applications in the cabin of commercial aircraft". From 2015 to 2023, Professor Neumeyer headed the Polymers Business Unit of Neue Materialien Bayreuth GmbH. His areas of work included the topics of fiber-reinforced plastics, particle foams, special injection molding processes and additive manufacturing with plastics.

In addition, sustainability aspects and their quantitative evaluation represent a cross-cutting theme of his work. In addition, he was a lecturer at the University of Bayreuth in the subject "Polymer Composites" and a member of the expert panel "Additive Manufacturing" at the Bavarian State Ministry of Economic Affairs, Regional Development and Energy. From July 2016 to December 2022, in addition to his work at Neue Materialien Bayreuth, he was also Managing Director of the industry network for polypropylene particle foams "EPP-Forum e.V.".

SEPTEMBER

Enthusiasm for Young Researchers

At the MI(N)Tmachwelt organized by ZukunftsRegion Westpfalz e.V. on 8 and 9 September 2023, children and young people were inspired by the fascinating world of STEM, science, technology, engineering and mathematics. The IVW was represented with a stand and a workshop. Numerous children and young people took the opportunity to experiment and explore STEM phenomena.

DECEMBER

UNIMOG / CVC

On December 7, 2023, the sixth network meeting of the joint project "WaVe" took place at our institute, where the speakers presented exclusive insights into the comprehensive results of the research project. The aim of the "WaVe" joint project, which is funded by the German Federal Ministry for Economic Affairs and Climate Protection, is to develop a hydrogen-based drive system for commercial vehicles in the medium-duty range. This drive system is being tested in field trials using various demonstrators, including a UNIMOG and a tracked vehicle. At the heart of the drive system is a new type of hydrogen combustion engine, which is supplemented with all the system components required for operation.

Mr. Geisler from Daimler Truck AG presented the first hydrogen-powered UNIMOG demonstrator with road approval and a successful mower test. Dr. Motsch-Eichmann from the Leibniz Institute for Composite Materials presented the tank system developed as part of the joint project. Dr. Bauer from ITK Engineering GmbH reported on the challenges and solutions in the development of safety concepts for the hydrogen-powered UNIMOG and tracked vehicle demonstrators.

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S. Arweiler-Böllert, M. Liesegang, T. Beck, J. Jungbluth, and S. Schmeer, „Relation between interface geometry and tensile shear strength of ultrasonically welded joints", *The Journal of Materials Engineering and Performance*, vol. 32, p. 10469-10485, 2023, doi: 10.1007/s11665-023-08325-2

C. Becker, J. Hausmann, J. Krummenacker, and N. Motsch-Eichmann, "First conclusions on damage behaviour of recycled carbon staple fibre yarn using x-ray and acoustic emission techniques", *MDPI Materials*, vol. 16, no. 13, p. 4842, 2023, doi: 10.3390/ma16134842

Y. Chen, A. Klingler, K. Fu, and L. Ye, "3D printing and modelling of continuous carbon fibre reinforced composite grids with enhanced shear modulus", *Engineering Structures*, vol. 286, p. 116165, 2023, doi: 10.1016/j.engstruct.2023.116165

M. Detzel, P. Mitschang, and U. Breuer, „New approach for processing recycled carbon staple fiber yarns to unidirectionally reinforced recycled carbon staple fiber tape", *MDPI Polymers Journal*, Special Issue "Manufacturing of Polymer-Matrix Composites", vol. 15, no. 23, p. 4575, 2023, doi: 10.3390/polym1523457

M. Eckrich, P. A. Arrabiyeh, A. M. Dlugaj, and D. May, "Placement defects in thermoset-impregnated rovings deposited along curved paths", *Polymer Composites*, vol. 44, no. 6, p. 3634-3645, 2023, doi: 10.1002/pc.27350

Esha and J. Hausmann, "Material characterization required for designing satellites from fiber-reinforced polymers", *Journal of Composites Science*, vol. 7, no. 12, p. 515, 2023, doi: 10.3390/jcs7120515

G. Ferreres, S. Pérez-Rafael, A. G. Morena, T. Tzanov, and L. Gryshchuk, "Influence of enzymatically hydrophobized hemp protein on morphology and mechanical properties of bio-based polyurethane and epoxy foams", *MDPI Polymers Journal*, vol. 15, no. 17, p. 3608, 2023, doi: 10.3390/polym15173608

J. Hausmann, S. Schmidt, and Esha, „Improved mean value-amplitude method for determination of orientation-dependent modulus of short fiber-reinforced thermoplastics", *Advanced Engineering Materials*, vol. 25, no. 12, p. 2300221, 2023, doi: 10.1002/adem.202300221

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H. Pérez-Martín, S. Buchalik-Bopp, B. Güttler, P. Mackenzie, A. Baidak, C. M. Ó Brádaigh, and D. Ray, "Effect of crystallinity and morphology on the mechanical properties of CF/PEKK composites manufactured under compression moulding and automated tape placement", *Materials Today Communications*, vol. 36, p. 106442, 2023, doi: 10.1016/j.mtcomm.2023.106442

F. M. G. Ramírez, R. D. F. Moreira, and M. F. S. F. de Moura, "Influence of adhesive fillets on fatigue behaviour of single-strap composite repairs", *Strain*, vol. 59, no. 5, p. 12454, 2023, doi: 10.1111/str.12454

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M. Salmins, F. Gortner, and P. Mitschang, "Challenges in manufacturing of hemp fiber-reinforced organo sheets with a recycled PLA matrix", *MDPI Polymers Journal*, Special Issue "Manufacturing of Polymer-Matrix Composites", vol. 15, no. 22, p. 4357, 2023, doi: 10.3390/polym15224357

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Special Publications

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F. M. González Ramírez, L. G. M. Lise, A. Baumann, F. Nowacki, I. Kunzler, and J. Hausmann. "Stacking sequence effect on the fatigue behavior of single lap shear bonded joints", presented at the Symposium – ICAF, The International Committee on Aeronautical Fatigue and Structural Integrity, Delft, Netherlands, 2023, https://www.icaf.aero/icaf2023/proceedings/display_manuscript/31.htm

Specialized Conferences

A. Baumann and J. Hausmann, "Correlating composite fatigue to its matrix properties", presented at the *Fatigue 2022+1*, Hiroshima, Japan, 2023.

A. Baumann and J. Hausmann, "Effect of high energy radiation on technical polymers" presented at the *6oth ISC, Ilmenau Scientific Colloquium of Technische Universität Ilmenau*, Ilmenau, 2023.

U. Blass, T. Heydt, N. Motsch-Eichmann, J. Hausmann, "Development of a hybrid process for the production of personalized and structurally optimized 3D-printet orthoses", presented at the *ICCM23, 23rd International Conference on Composite Materials*, Belfast, Northern Ireland, 2023.

U. Blass, T. Heydt, N. Motsch-Eichmann, and J. Hausmann, "Development of a hybrid process for the production of personalized and structurally optimized 3D-printed ankle-foot orthoses", presented at the *WCORT, 7th Annual World Congress of Orthopaedics*, Lisbon, Portugal, 2023.

C. Becker, N. Motsch-Eichmann, and J. Hausmann, "Mechanical performance of unidirectional rCFRP for load-bearing applications", presented at the *SE23, SAMPE Europe Conference 2023 of Society for the Advancement of Material and Process Engineering Europe*, Madrid, Spain, 2023.

C. Becker, N. Motsch-Eichmann, and J. Hausmann, "Influence of recycled carbon fiber (rCF) matrix interphase on mechanical properties and damage behavior", presented at the *FEMS EUROMAT 23, Materials Science and Technology in Europe Conference of Federation of European Materials Societies*, Frankfurt/Main, 2023.

C. Becker, N. Motsch-Eichmann, and J. Hausmann, "Characterization of the damage behavior of recycled carbon fiber with x-ray and acoustic emission techniques", presented at the *ICCM23, 23rd International Conference on Composite Materials*, Belfast, Northern Ireland, 2023.

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B. Boos, H. Yagdjian, L. Mix, and M. Gurka, "Amplitude reduction analysis of guided ultrasonic waves in anisotropic composite structures with complex geometry", presented at the *Schall 23*, Wetzlar, 2023.

P. Cabulis, U. Cabulis, M. Kirpluks, A. Bansal, M. Sanchez-Hernandez, and L. Gryshchuk, "Demonstration of the benefits of thermal insulation from renewable materials for the building industry", presented at the *RRB2023, International Conference on Renewable Resources & Biorefineries*, Riga, Latvia, 2023.

S. Cassola, Tim Schmidt. Miro Duhovic, David May, Dinesh Natarajan, and Denis Korolev, "Machine learning assisted multiscale simulation for liquid composite molding", presented at the *Leibniz MMS Days 2023, 6th Leibniz Network Mathematical Modelling and Simulation 2023*, Potsdam, 2023.

S. Cassola, M. Duhovic, M. Salmins, and P. Mitschang, "Simulating the hot press processing of structural thermoplastic foams", presented at the *14th European LS-DYNA Conference*, Baden-Baden, 2023.

M. Chijiiwa, M. Schäfer, P. Mitschang, and J. A. L'huillier, "The effect of temporal pulse overlaps to the morphology on stainless steel 304 by ps laser micro structuring", presented at the *LiM 2023, Lasers in Manufacturing Conference 2023*, Munich, 2023.

A. Dlugaj, C. de Vita, P. A. Arrabiyeh, and D. May, "Characterization of sequential trial-curable off-stoichiometric amine-epoxy thermosets with ionic liquids", presented at the *11th Conference on Times of Polymers & Composites*, Ischia, Italy, 2023.

A. Faas and D. May, "Resin transfer molding of hollow parts with in situ generation of polyurethane cores", presented at the *SE23, SAMPE Europe Conference 2023 of Society for the Advancement of Material and Process Engineering Europe*, Madrid, Spain, 2023.

A. Gebhard and E. Kuksa, "The role of transfer films in the transition between abrasive and adhesive wear in dry sliding of PA6-GR15 on 52100 steel", presented at the *ECOTRIB 2023*, Bari, Italy, 2023.

L. Gryshchuk, W. Almustafa, G. Grun, and S. Grishchuk, "New bio-based polyesters for biodegradable textile, packaging and shoe applications", presented at the *ISTRBPC-2023, 6th International Conference on Biopolymers and Polymer Chemistry*, online, 2023.

L. Gryshchuk and C. Pirro, "Possible ways for chemical recycling of cyanate ester, epoxy and polyurethane composites, properties and application of recyclates", presented at the *PolyScience2023, 3rd Global Summit on Polymer Science and Composite Materials*, Lisbon, Portugal, 2023.

L. Gryshchuk, "Bio-based composite epoxy foams for constructive applications", presented at the *Plastics and Composites, 3rd Global Conference on Polymers*, Barcelona, Spain, 2023.

T. Hoffmann, M. Duhovic, P. Mang, and P. Mitschang, "Decoupled electromagnetic simulation of the induction welding process of CFRTP Composites", presented at the *ICCM23, 23rd International Conference on Composite Materials*, Belfast, Northern Ireland, 2023.

T. Hoffmann, M. Duhovic, and P. Mitschang, "A decoupled multiphysics approach for computationally efficient continuous induction welding simulation of CFRTPs", presented at the *14th European LS-DYNA Conference*, Baden-Baden, 2023.

N. Hudzenko, V. Grishchenko, N. Busko, and Redko, "Polyurethane hybrid composites functionalized with bio-based components", presented at the *KyivTex & Fashion, VII International Scientific-Practical Conference*, Kyiv, Ukraine, 2023.

N. Hudzenko and L. Gryshchuk, "Bio-based hybrid non-isocyanate polyurethane (NIPU)/epoxy foams", presented at the *4th International Scientific Conference Chemical Technology and Engineering*, Lviv, Ukraine, 2023.

J. Hüppauff, V. Nagaraj, and N. Motsch-Eichmann, "Development of an innovative thermoplastic door-surround-structure for a single aisle-aircraft", presented at the *SE23, SAMPE Europe Conference 2023 of Society for the Advancement of Material and Process Engineering Europe*, Madrid, Spain, 2023.

J. Hüppauff, V. Nagaraj, N. Motsch-Eichmann, and J. Hausmann, "Entwicklung einer integralen thermoplastischen Türumgebung", presented at the *DLRK2023, Deutscher Luft- und Raumfahrtkongress 2023*, Stuttgart, 2023.

J. Hüppauff, N. Motsch-Eichmann, T. Pfaff, and J. Hausmann, "Novel structure-integrated hydrogen storage systems for aerospace and automotive applications", presented at the *ICCM23, 23rd International Conference on Composite Materials*, Belfast, Northern Ireland, 2023.

J. Janzen and D. May, "Solid epoxy prepregs with patterned resin distribution for out-of-autoclave processing", presented at the SE23, *SAMPE Europe Conference 2023 of Society for the Advancement of Material and Process Engineering Europe*, Madrid, Spain, 2023.

J. Jungbluth, et al., "Characterization and improvement of SMA-polymer interface in active hybrid composites", presented at the *ICCM23, 23rd International Conference on Composite Materials*, Belfast, Northern Ireland, 2023.

M. Kaiser, M. Kunzler, and M. Gurka, "Characterization of active shape control SMAHCS under the influence of various ambient temperatures", presented at the *ICCM23, 23rd International Conference on Composite Materials*, Belfast, Northern Ireland, 2023.

S. T. Kaysser, C. A. Keun, M. Ritschel, S. Steffen, J. Kürsten, B. Schug, and F. Gortner, "Development of translucent and flame retardant epoxy-SMC for aircraft cabin application", presented at the *SAMPE Conference 2023, North America Society for the Advancement of Material and Process Engineering*, Seattle, Washington, USA, 2023.

A. Klingler, B. Wetzel, and J.-K. Krüger, "Vitrimer phase transitions from the perspective of ultra-slow volume changes", presented at the *EUPOC 2023*, Bertinoro, Italy, 2023.

D. Korolev, S. Cassola, M. Hintermüller, T. Schmidt, M. Duhovic, and D. May "Physics informed neural networks for permeability predictions of fibrous microstructures", presented at the *AIMSE 2023, 1st Conference on Artificial Intelligence in Materials Science and Engineering*, Saarbrücken, 2023.

Specialized Conferences

A. Krämer, J. Broeining, and P. Mitschang, "Investigations on the mechanical property robustness of natural fibre reinforced polymer composites (NFRPC) under varying processing conditions", presented at the *FEMS EUROMAT 23, Materials Science and Technology in Europe Conference of Federation of European Materials Societies*, Frankfurt/Main, 2023.

A. Krämer and P. Mitschang, "Development of a thermoplastic prepreg based on a partially polymerized reactive resin system", presented at the *SE23, SAMPE Europe Conference 2023 of Society for the Advancement of Material and Process Engineering Europe*, Madrid, Spain, 2023.

J.-K. Krüger, B. Wetzel, and A. Klingler, "The topology freezing phenomenon of vitrimers as seen by static and dynamic thermo-physical properties", presented at the *ACEX2023, 16th International Conference on Advanced Computational Engineering and Experimenting*, Heraklion, Greece, 2023.

M. Kunzler, C. Queck, and M. Gurka, "4D-printing of hybrid composites integration of shape memory alloy wires on material level using SLA printing technique",presented at the *ICCM23, 23rd International Conference on Composite Materials*, Belfast, Northern Ireland, 2023.

J. Lee, M. Duhovic, T. Allen, D. May, and P. Kelly, "Rate-dependent effects in transverse liquid composite molding manufacturing processes", presented at the *FPCM-15, 15th International Conference on Flow Processes in Composite Materials*, West Lafayette, Indiana, USA, 2023.

J. Lee, M. Duhovic, T. Allen, D. May, and P. Kelly, "Transverse liquid composite molding: Development and comparison of process models", presented at the *ICCM23, 23rd International Conference on Composite Materials*, Belfast, Northern Ireland, 2023.

N. Motsch-Eichmann, T. Pfaff, J. Hüppauff, and J. Hausmann, "New conformable hydrogen storage system for mobile applications", presented at the *SE23, SAMPE Europe Conference 2023 of Society for the Advancement of Material and Process Engineering Europe*, Madrid, Spain, 2023.

N. Motsch-Eichmann, T. Pfaff, and U. Blass, "Lasttragende Wasserstoffspeicher für Luftfahrtanwendungen", presented at the *DLRK2023, Deutscher Luft- und Raumfahrtkongress 2023*, Stuttgart, 2023.

N. Motsch-Eichmann, T. Rief, D. May, and J. Hausmann, "Hollow fiber-reinforced structural cores for complex part manufacturing", presented at the *ICCM23, 23rd International Conference on Composite Materials*, Belfast, Northern Ireland, 2023.

N. Motsch-Eichmann, J. Krummenacker, Y. N. Becker, J. Hausmann, and U. P. Breuer, "Hybrid fibre reinforced composite pedicle screw system", presented at the *WCORT, 7th Annual World Congress of Orthopaedics*, Lisbon, Portugal, 2023.

V. Nagaraj, N. Motsch-Eichmann, and J. Hüppauff, "Advancements in thermoplastic composites for next generation aircrafts: A study on topology optimization and simulation methodologies for the design of door surrounding structures", presented at the *SE23, SAMPE Europe Conference 2023 of Society for the Advancement of Material and Process Engineering Europe*, Madrid, Spain, 2023.

V. Nagaraj, N. Motsch-Eichmann, J. Hausmann, and D. Peeters, "Structural optimization to derive feasible and manufacturable tailored fiber placement (TFP) designs", presented at the *ICCM23, 23rd International Conference on Composite Materials*, Belfast, Northern Ireland, 2023.

D.K. Natarajan, T. Schmidt, M. Nuske, S. Cassola, M. Duhovic, and D. May, "Data-driven emulators for microscale permeability prediction", presented at the *AIMSE 2023, 1st Conference on Artificial Intelligence in Materials Science and Engineering*, Saarbrücken, 2023.

M. Salmins and P. Mitschang, "Optimized process design for the production of bio-based rPLA organo sheets with bast fiber reinforcement", presented at the *SE23, SAMPE Europe Conference 2023 of Society for the Advancement of Material and Process Engineering Europe*, Madrid, Spain, 2023.

J. Schlimbach, A. Nuhn, and Esha, "Hybrid injection molding for structurally parts", presented at the *AMI Reinforced Thermoplastics Conference 2023 of Applied Market Information Ltd.,* Cologne, 2023.

J. Schlimbach, "Additive manufacturing for advanced composite applications", presented at the *WCAM 2023, 9th Annual World Congress of Advanced Materials*, Tokyo, Japan, 2023.

J. Schlimbach, "FIFDM: Multi-material manufacturing for composite parts enabled by FIFDM", presented at the *WCSM 2023, World Congress of Smart Materials*, Barcelona, Spain, 2023.

T. Schmidt, D. K. Natarajan, S. Cassola, D. May, and M. Duhovic, "Machine learning for permeability determination of fibrous structures", presented at the *FPCM-15, 15th International Conference on Flow Processes in Composite Materials*, West Lafayette, Indiana, USA, 2023.

D. Schommer, M. Duhovic, T. Hoffmann, K. Schladitz, F. Gortner, D. May, J. Hausmann, and P. Mitschang, "Development of characterization and simulation methods for carbon fiber sheet molding compounds", presented at the *FPCM-15, 15th International Conference on Flow Processes in Composite Materials*, West Lafayette, Indiana, USA, 2023.

D. Schommer, M. Duhovic, D. May, J. Hausmann, H. Andrä, and K. Steiner, "A user-defined Folgar-Tucker-based fiber orientation material model for compression molding of fiber/polymer-compounds", presented at the *14th European LS-DYNA Conference*, Baden-Baden, 2023.

N. Sindhe Narayana Rao, D. Schommer, T. Rief, M. Duhovic, N. Motsch-Eichmann, and J. Hausmann, "Digital process chain for thermoplastic structural components with local unidirectional reinforcements for aerospace applications", presented at the *SE23, SAMPE Europe Conference 2023 of Society for the Advancement of Material and Process Engineering Europe*, Madrid, Spain, 2023.

N. Sindhe Narayana Rao, T. Pfaff, U. Schmitt, N. Motsch-Eichmann, and J. Hausmann, "A double-wall CFRP hydrogen storage and distribution system as a structural component in aircraft applications", presented at the *DLRK2023, Deutscher Luft- und Raumfahrtkongress 2023*, Stuttgart, 2023.

E. Syerko, T. Schmidt, K. Schladitz, D. May, C. Binetruy, L. Silva, S.V. Lomov, and S. Advani, "First insights from the second mesoscale stage of the virtual permeability benchmark on engineering textiles", presented at the *Workshop on benchmarking and standardization activities, FPCM-15, 15th International Conference on Flow Processes in Composite Materials*, West Lafayette, Indiana, USA, 2023.

M. O. Voltz, O. Zöllner, and P. Mitschang, "Methodology for characterizing the fiber print through and overall surface quality for unidirectional reinforced composites", presented at the *ICCM23, 23rd International Conference on Composite Materials*, Belfast, Northern Ireland, 2023.

S. Weidmann, T. Hoffmann, M. Duhovic, J. Weber, and P. Mitschang, "Cutting-edge joining processes for TP-FRPC and multi-material structures made of TP-FRPC and metals", presented at the *PIAE 2023, Plastics in Automotive Engineering Congress 2023* of VDI, Mannheim, 2023.

N. Wurm, P. Frohn-Sörensen, J. Böcking, A. Faas, J. Janzen, H.-P. Hartmann, D. May, and B. Engel, "Umformverhalten faserverstärkter Thermoplasthalbzeuge beim ebenen Schwenkbiegen", presented at the *XLI. Verformungskundliches Kolloquium*, Leoben, Austria, 2023.

H. Yagdjian and M. Gurka, "Shock Response Spectrum (SRS) Analyse als alternative Methode zur Auswertung von Infrarot-Thermografie (IRT) Daten", presented at the *DACH Jahrestagung 2023*, Friedrichshafen, 2023.

Internal Colloquia

January 3, 2023
Alexander Faas
In situ core generation for producing hollow profiles in RTM

February 6, 2023
Stefan Weidmann
Challenges in Joining Metals with Thermoplastic FRP

Andreas Kenf
TopTape – Efficient Test Methods for Process Optimization and Quality Control of Wound Tubes

March 6, 2023
Emmanuel Isaac Akpan
New Life for Waste Wood Through Localized Healing of Macro and Micro Defects

Francis González Ramírez
Hygrothermal Effect on the Fracture / Fatigue Behavior of Adhesively Bonded Repair

April 3, 2023
Jan Janzen
Novel Prepregs Based on Solid Thermosets

Benedikt Boos
SHM-Systems for Composite Structures

May 8, 2023
Manuel Kunzler
4D Printing of Shape Memory Alloy Hybrid Composites

Maximilian Eckrich
Development of a Process Chain for a Topology-Optimized Design for Manufacturing by Wet Fiber Placement

June 5, 2023
Ulrich Blass
Development of a Digitized Process for the Production of Novel Thermoplastic Aviation Struts

Stefano Cassola
Machine Learning Based Surrogate Modelling for Microscale Permeability Simulations

July 3, 2023
Florian Gortner
Translucent and Flame-Retardant Sheet Molding Compounds

Peter Arrabiyeh
Process Technologies for Wet Fiber Placement

October 9, 2023
Thomas Hoffmann
Decoupled Electromagnetic Simulation of the Continuous Induction Welding Process of CFRTP Composites

Martin Detzel
Production of rCF Tapes Based on Staple Fiber Yarns

November 6, 2023
Andreas Klingler
Malleability of Cross-Linked Polymers

Benedikt Bergmann
Friction Measurement on Fibers for the Filament Winding

December 4, 2023
Jannis Hüppauff
Design of Thermoplastic Aerospace Structures

Guest Scientists

Prof. Dr. Dr. h.c. Jan Kristian Krüger
Universität des Saarlandes, Germany
since October 1, 2019
(sponsored by Saarland University)

Prof. Nataliia V. Hudzenko
Institute of Macromolecular Chemistry,
National Academy of Sciences of Ukraine
June 1, 2022 – May 31, 2023
(Volkswagen Foundation –
Guest program for escaped Ukrainian guest scientists)

Ms. Hui Wen Yong
McGill University Montreal, Canada
May 15 – August 15, 2023
(DAAD Rise Professional)

Mr. Murat Çelik
The University of Edinbrugh, UK
June 19 – August 26, 2023
(DAAD Rise Professional)

Dr. Luis Felipe Sesé
Universidad de Jaén, Spain
June 22 – July 22, 2023
(sponsored by Universidad de Jaén)

Ms. Jeeeun Lee
University of Auckland, New Zealand
July 1 – July 31, 2023
(funded by University of Auckland)

Dr. Maryna Novitska
Institute of Macromolecular Chemistry,
National Academy of Sciences of Ukraine
June 1, 2022 – May 31, 2023
(Volkswagen Foundation –
Guest program for escaped Ukrainian guest scientists)

Prof. Dr. Ga Zhang,
Mr. Guitao Li,
Mr. Yongkun Xu
Lanzhou Institute of Chemical Physics,
Chinese Academy of Sciences, China
October 1 – October 15, 2023
(funded by Chinese Academy of Sciences)

Doctorates

March 1, 2023
Björn Willenbacher, M.Sc.
"Bestimmungsmethoden für das transversale Imprägnier- und Deformationsverhalten textiler Verstärkungsstrukturen"

Chairperson:
Prof.-Dr.-Ing. Joachim Hausmann, IVW

Report:
Prof. Dr.-Ing. Peter Mitschang, IVW
Prof. Dr. Paolo Ermanni, ETH Zürich, Switzerland
PD Dr.-Ing. habil. David May, IVW

July 27, 2023
Dipl.-Ing. Stefan Weidmann
"Diskontinuierliches induktives Fügen glasfaserverstärkter Thermoplaste mit Stahl"

Chairperson:
Prof. Dr.-Ing. Paul Ludwig Geiß, RPTU

Report:
Prof. Dr.-Ing. Peter Mitschang, IVW
Prof. Dr. Frank Balle, Albert-Ludwigs-Universität Freiburg

October 5, 2023
Dipl.-Ing. Max Kaiser
„Transient electro-thermomechanical modeling of shape adaptive Shape Memory Alloy Hybrid Compo-sites under influence of ambient temperature and static external load"

Chairperson:
Prof.-Dr.-Ing. Joachim Hausmann, IVW

Report:
Prof. Dr.-Ing. Ulf Breuer, IVW
Prof. Dr.-Ing. Stefan Seelecke, Universität des Saarlandes; PD Dr. rer. nat. habil. Gurka, IVW

International Cooperations

- Johannes Kepler University Linz, Austria
- University of Leoben, Austria
- University of Sydney, Australia
- Katholieke Universiteit Leuven, Belgium
- The São Paulo Research Foundation, FAPESP, Sao Paulo, Brazil
- McGill University, Montreal, Canada
- IMT Mines-Ales, Alès, France
- University of Ioannina, Greece
- Institute for Polymers, Composites and
- Biomaterials, Catania, Italy
- Polytechnic University of Milan, Italy
- Luxembourg Institute of Science and Technology, Luxembourg
- University of Luxembourg , Luxembourg
- Delft University of Technology,
- Netherlands
- CENTI / Citeve, Vila Nova de Famalicao, Portugal
- University of Auckland, New Zealand
- University of Ljubljana, Faculty of Mechanical Engineering, Slovenia
- Technical University of Catalonia, Barcelona, Spain
- University of A Coruña, Spain
- University of Jaén, Spain
- Luleå University of Technology, Sweden
- Research Institutes of Sweden AB (RISE), Sweden
- ETH Zurich, Switzerland
- National Composites Centre, Bristol, UK
- National Physical Laboratory, Teddington, UK
- University of Edinburgh, UK
- University of Nottingham, UK
- National Acadamy of Sciences of Ukraine, Kyiv, Ukraine
- Brigham Young University, Provo, USA
- Texas A&M University, College Station, USA
- University of Delaware, Newark, USA
- University of Sheffield, UK
- University of Washington, Seattle, USA

Memberships

- AVK Industrievereinigung Verstärkte Kunststoffe e.V., www.avk-tv.de
- AiF InnovatorsNet www.aif-ftk-gmbh.de/index.html
- CUeV Composites United e.V., www.composites-united.com
- CU WEST Regionalabteilung des Composites United e.V.
- CVC Commercial Vehicle Cluster – Nutzfahrzeug GmbH, www.cvc-suedwest.com
- DGLR Deutsche Gesellschaft für Luft- und Raumfahrt e.V., www.dglr.de
- DGM Deutsche Gesellschaft für Materialkunde e.V., www.dgm.de
- DGZfP Deutsche Gesellschaft für zerstörungsfreie Prüfung e.V., www.dgzfp.de
- DIN Deutsches Institut für Normung e.V., www.din.de
- European Alliance for SMC/BMC www.smcbmc-europe.org
- FGW Forschungsgemeinschaft Werkzeuge und Werkstoffe e.V., www.fgw.de
- fimatec fiber materials technology network, www.iws-nord.de/foerdermittelberatung/zim-netzwerke
- GfT Gesellschaft für Tribologie e.V., www.gft-ev.de
- IASB Industrieausschuss Strukturberechnungs-unterlagen, www.lth-online.de
- Kompetenznetz Adaptronik e.V. www.kompetenznetz-adaptronik.de
- RCI – RENEWABLE CARBON INITIATIVE www.renewable-carbon-initiative.com
- SAMPE Europe Society for the Advancement of Material and Process Engineering, www.sampe-europe.org
- Science and Innovation Alliance Kaiserslautern e.V. www.science-alliance.de
- Unternehmensnetzwerk Erfolgsfaktor Familie www.erfolgsfaktor-familie.de
- VDI Verein Deutscher Ingenieure e.V., www.vdi.de
- Zukunftsregion Westpfalz e.V. www.zukunftsregion-westpfalz.de

Expert Panels / Reviews

- Advanced Materials Engineering (AME)
- AiF – Arbeitsgemeinschaft industrieller Forschungsvereinigungen
- Alexander von Humboldt-Stiftung
- Arbeitskreis „endlosfaserverstärkte Thermoplaste“ der AVK e.V.
- Bayerische Forschungsstiftung
- BMWK Expertengruppe Elektropower
- BMBF, Projektträger Jülich
- Composites United e.V. – Arbeitsgruppen Biocomposites, Smart Structures, Thermoplastische Composites, Bearbeitung
- CU West, Vorstand
- CVC Rheinland-Pfalz
- DAAD – Deutscher Akademischer Austauschdienst
- Deutsche Gesellschaft für zerstörungsfreie Prüfung e.V., Fachausschüsse „Faserkunststoff-verbunde“, „Zustandsüberwachung“, „Structural Health Monitoring“, „Akustische Emission“
- DGLR – Deutsche Gesellschaft für Luft- & Raumfahrt e.V.
- DGM e.V. – Fachausschuss „Hybride Werkstoffe & Strukturen“
- DIN – Deutsches Institut für Normung, Fachbereich „Duroplast- & Thermoplast-Formmassen“, Normenausschüsse „Verstärkte Kunststoffe & härtbare Harze“ & „Verbundwerkstoffe – Luft & Raumfahrt“, Beirat Normenausschusses „Kunststoffe“
- DLR – Deutsches Zentrum für Luft- & Raumfahrt
- DLRK – Deutscher Luft- & Raumfahrtkongress
- DFG Normalverfahren & Sonderforschungsbereich Begutachtung
- European Society for Composite Materials
- European Structural Integrity Society (ESIS), Technical Committee 4 (TC4) Polymers, Polymer Composites and Adhesives
- Fraunhofer Leistungszentrum Simulations- und Softwarebasierte Innovation, Kaiserslautern, Executive Board
- FVA – Forschungsvereinigung Antriebstechnik e.V., PA Kunststoffe
- Gemeinschaftsausschuss Verbundwerkstoffe (GAV)
- Industrieausschuss Strukturberechnungsunterlagen (IASB) des Luftfahrttechnischen Handbuchs (LTH)
- Innovationscampus Mobilität der Zukunft des Landes Baden-Württemberg
- ISO – Member of the Geman delegation ISO Technical Committee „Plastics“ TC61/SC13 “Composites and reinforced fibers”
- ISO Standardization Project – Working Group Leader “Process Simulation”
- Kompetenznetz Adaptronik e.V.
- Netherlands Organisation for Scientific Research (NWO)
- Östereichische Forschungsförderungsgesellschaft FFG
- Stiftung Industrieforschung
- Rat für Technologie des Landes
- Rheinland-Pfalz
- RCI – The renewable carbon initiative
- VDMA Arbeitsgemeinschaft Hybride Leichtbau Technologien

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