DITF

DEUTSCHE INSTITUTE FÜR
TEXTIL+FASERFORSCHUNG

ANNUAL REPORT 2022

TEXTILE FUTURE

DITF.de

OPEN THE WINDOW
INTO THE WORLD OF TEXTILE

TAKE A LOOK INTO THE DETAILS OF OUR RESEARCH, IN IDEAS AND INNOVATIONS FROM THE GERMAN INSTITUTES OF TEXTILE AND FIBER RESEARCH DENKENDORF

DEUTSCHE INSTITUTE FÜR
TEXTIL+FASERFORSCHUNG

ANNUAL REPORT 2022

FOREWORD

Dear Reader,

Once again, a challenging year lies behind us. The Russian war of aggression on Ukraine and the developments that followed have decisively changed the political and economic framework.

The energy crisis and pressing climate protection issues are setting new priorities for our work and are bringing the topics of renewable energies, energy efficiency and energy storage, effective use of resources, circular economy and renewable raw materials more and more into focus. Our new key visual, which graces the cover, represents this development.

The future is textile!

As an application-oriented research institution working at the interface between science and industry, we support our customers and partners in meeting the current challenges. Textile products and processes that we develop at the DITF are sought-after problem solvers for many future tasks and are already being used for a wide range of applications as efficiency catalysts, environmental protection enhancers and climate savers.

Progress in mobility, for example, is closely linked to fiber innovations that give us a head start in energy and resource efficiency. Ultralight fiber composite components offer particular potential for this and include the possibility of function integration and optimization.

The same applies to the construction sector. Here, fiber-based materials are increasingly expanding the existing range of materials and opening up new, forward-looking perspectives in terms of functionality, sustainability, aesthetics and, not least, cost-effectiveness. Here, too, important goals are the minimization of resource consumption, recycling-friendly construction and the complete elimination of fossil fuels. Fiber-based materials can make a decisive contribution to this.

The annual report reflects the diversity of topics and projects in the application fields of mobility, architecture and construction, energy, environment and resource efficiency, health and care, clothing and home textiles, and production technologies. A total of 24 project reports provide insight into our research, ideas and innovations from the DITF. We succinctly summarize the fascinating possibilities with the vision of the DITF in one sentence and in just four words: The future is textile!

Invest BW and prototype funding

The transfer and exploitation of research results were particularly supported by funding programs of the state in the past year. In Invest BW, the largest sector-open, single-company funding program in the history of Baden-Württemberg to date, the DITF were able to win a total of 9 projects in the various funding rounds. In the prototype funding program, the DITF, together with the Natural and Medical Sciences Institute, are also involved with a project. We would like to express our sincere thanks to the state of Baden-Württemberg and our corporate partners for their financial support and excellent cooperation.

Climate neutrality 2023

The current situation also requires a critical analysis of our own energy consumption and CO_2 footprint. The DITF want to make their contribution to the state's climate goals and become climate neutral by 2030. At the same time, the energy and heating requirements at the DITF are to be drastically reduced and covered to a considerable extent by regenerative energy sources. Initial measures such as an extensive investment in photovoltaic systems have already been initiated with the support of the Baden-Württemberg Ministry of Economics. A more far-reaching, holistic transformation concept will be developed and implemented in the coming years.

Peter Steiger Prof. Dr. rer. nat. habil. Michael R. Buchmeiser Prof. Dr.-Ing. Götz T. Gresser

Shaping the future – DITF strategy

Every five years, the DITF strategy is reviewed and adapted to current developments. The strategy defines: What we stand for. Where we want to go. What long-term measures we need. And most importantly, how we can see whether we are achieving our goals and whether the strategy is successful.

In 2022, we began implementing the strategy we had developed the year before. The focus was on restructuring the research fields (see pages 14/15) and consistently working according to the new strategy map, which backs up the agreed targets with concrete key figures. The start has been successful and motivates further changes to fill the strategy with life.

100+1 years of DITF

A special highlight in 2022 was the anniversary celebration of the DITF, which took place one year late due to the Covid-19 pandemic. More than 300 guests from politics, business and science and the employees of the DITF experienced a glittering celebration at the Haus der Wirtschaft in Stuttgart (see page 10/11). The motto of the anniversary "Let's celebrate the textile future" could not have been better chosen.

We would like to express our sincere thanks to all our partners, sponsors, supporters and, above all, our employees for their passionate and valuable commitment. We look forward to continued collaboration and cooperation to drive the much needed transformation together.

We wish all readers of the DITF Annual Report an inspiring read!

Sincerely

Your DITF Board

Prof. Dr.-Ing.
Götz T. Gresser

Prof. Dr. rer. nat. habil.
Michael R. Buchmeiser

Peter Steiger

TABLE OF CONTENTS

Foreword . . . 4

Table of contents . . . 6

DITF . . . 8

DITF.100 – Let's celebrate the textile future! . . . 10

What we offer . . . 12

DITF Research fields . . . 14

Figures – data – facts . . . 16

Networks and collaborations . . . 17

Areas of application . . . 19

Research projects, trends and highlights

- Architecture and construction . . . 20
- Health and care . . . 26
- Mobility . . . 32
- Energy, environment and resource efficiency . . . 38
- Production technologies . . . 44
- Clothing and home textiles . . . 50

DITF bodies . . . 56

Association of DITF sponsors . . . 58

Imprint . . . 62

Documentation separate from the annual report provides an overview of

> DITF points of contact

> Publicly funded research projects

> Published final reports, publications, lectures, press releases

> Dissertations, awards

> Events, trade shows, exhibitions

> Patents

> Bodies, scientific advisory councils

Orders: info@ditf.de

DEUTSCHE INSTITUTE FÜR TEXTIL+FASERFORSCHUNG

GERMAN INSTITUTES OF TEXTILE AND FIBER RESEARCH DENKENDORF

FUTURE TEXTILES

The areas of textile chemistry and man-made fibers, textile and process engineering, and management research are united under the umbrella of the DITF. With their main research areas, they together cover the entire production and value chain of fiber-based materials – from the molecule to the product. Their potential lies in their close connection. Together, they are paving the way for the textile future.

GERMAN INSTITUTES OF TEXTILE AND FIBER RESEARCH DENKENDORF

We think in textile systems. They are the key to innovation in many important industries and high-tech sectors.

The DITF form the largest textile research center in Europe

With more than 250 scientists and technical employees, the German Institutes of Textile and Fiber Research Denkendorf cover the entire production and value creation chain in textiles as the only textile research institution in the world. The DITF have been covering all the important textile topic fields since 1921. In their fields of activity the DITF belong to the world-leading research institutions.

Application-oriented research from molecules to products

The DITF carry out application-specific research over the entire textile production chain. With product- and technology-oriented innovations as well as modern management concepts, the Denkendorf researchers contribute to the competitiveness and safeguarding of both the German and European economy.

R&D services

The DITF are an important R&D partner for industrial and service companies in fields ranging from ideas to material research, the development of prototypes and industrial processes, from pilot production to testing. The DITF are an important supplier of innovative expertise, especially for small and medium enterprises that do not have their own R&D departments.

Industry partners

The DITF are partners with numerous local and international enterprises. They take part in public research processes or issue direct research assignments to the DITF. The DITF support and advise companies in the most important industrialized nations worldwide.

Technology and knowledge transfer in practice

The DITF quickly transfer sustainable research results into economic utilization and application. Our most important goal is the conversion of scientific knowledge into market-ready processes, products and services.

Teaching and practical further training

As one of the leading European research institutions in the field of textile technology, the DITF have a special responsibility to encourage young scientists. Therefore, training and further education are among the DITF's central tasks.

Numerous lecturing and research collaborations have been formed with regional universities. A collaborative research and lecturing association with Reutlingen University exists through the Center for Interactive Materials (CIM). The DITF also have a close connection with the University of Stuttgart in the form of three professorships as well as courses in other study subjects.

Professorships at the University of Stuttgart

Professorship in Macromolecular Substances and Fiber Chemistry – Institute of Polymer Chemistry
Prof. Michael R. Buchmeiser

Professorship in Textile Technology, Fiber-Based Materials and Textile Machinery – Institute of Textile and Fiber Technologies
Prof. Götz T. Gresser

Professorship for Diversity Studies in Engineering – Institute for Diversity Studies in Engineering
Prof. Dr. rer. pol. Dipl.-Ing. Meike Tilebein

DITF.100

LET'S CELEBRATE THE TEXTILE FUTURE!

300 guests celebrated 100+1 years of DITF

Stuttgart, Haus der Wirtschaft: Let's celebrate the textile future!

Like so many events during the Covid-19 pandemic, the anniversary celebration of the DITF had to be postponed. And so it was 100+1 years of textile research that was celebrated on 22.2.2022. Under the motto "Let's celebrate the textile future" the DITF had invited to the Haus der Wirtschaft in Stuttgart. A varied program with speeches, lectures, entertainment, an exhibition, music and good food awaited the more than 300 guests from politics, business, science and the employees of the DITF.

In his anniversary speech, Professor Michael R. Buchmeiser covered the long arc of textile research from 1921 to the present day. The claim of the founding fathers – consistent application orientation – still characterizes textile and fiber research in Denkendorf today.

The look back showed an impressive joint effort, for which Michael R. Buchmeiser thanked all those involved and in particular the employees of the DITF on behalf of the Executive Board.

The importance of textile research in Denkendorf for all future topics was emphasized by Dr. Nicole Hoffmeister-Kraut, Minister of Economics of the State of Baden-Württemberg, and Dr. Franziska Brantner, Parliamentary State Secretary at the Federal Ministry of Economics, in their welcoming addresses. They found much praise for the work of the DITF.

Exciting keynote speeches by Dr. Antje von Dewitz, VAUDE, Professor Klaus Müllen, Max Planck Institute for Polymer Research, and Peter Dornier, Lindauer Dornier, took up key future topics such as sustainability and digitalization.

During the break, the "Physikanten & Co." provided amusing and at the same time instructive "edutainment".

An exhibition in which the twelve competence and technology centers of the DITF showed examples of their research completed the successful framework for the anniversary celebration.

Instead of giveaways, the DITF erected a fog catcher (textile, of course) in Peru and thus supported a project of the WasserStiftung.

DITF Anniversary Film

A film on the occasion of the DITF anniversary takes a journey through time and shows impressions from the foundation of the German Research Institute for Textile Industry in Reutlingen-Stuttgart to today's pilot plants and laboratories of the modern research center in Denkendorf. Here, from the 1970s onwards, all areas of research came together: from chemistry to mechanical engineering, process engineering to economics.

Roll film!

Sponsors

We thank for the support:

DIENES
DILO GROUP – Engineering for Nonwovens
Dr. Petry Textile Auxiliaries
KARL MAYER GROUP
MATTES & AMMANN®
PLEVA Sensors and Controls
PMI The Wound Healing Company
SV Sparkassen Versicherung
Textechno textile testing technology
Triumph

FROM MOLECULE TO MARKET – WHAT WE OFFER

The DITF support you – starting from brainstorming through material research, development of prototypes and production processes, pilot manufacture and testing to advice on new business models. We orient ourselves to the needs of the industry and create market-ready products, processes and services for it.

Denkendorf Future Workshop

Innovations are rarely created by coincidence or simply by intuition. A structured innovation process is essential for creating new, market-ready and implementable ideas. The Denkendorf Future Workshop can help with this. It offers companies targeted and systematic support for brainstorming.

Applied research and development

We invest in preliminary research, make the latest results from fundamental and application-oriented research available to the textile sector, operate joint research, contract research and development on commission. From the molecule to the finished product and its entry onto the market we research and develop along the entire textile value creation chain and in the process, also develop business processes and models.

Testing services

Since their foundation the DITF have had test laboratories and offer a comprehensive service catalog for testing fibers, yarns, surfaces and textiles. Hardly any other institution offers such comprehensive technology for the research and testing of fiber-based materials and textiles. State-of-the-art analysis and testing techniques are available for examining textile-technical, chemical, biological and sensory testing processes.

Pilot factory

The DITF operate a pilot factory in which all the important technologies along the process chain are implemented. With this pilot factory we offer the industry a unique opportunity in the textile market for zero and small series manufacturing. Experienced staff, combined with the existing machinery park and well-equipped technical facilities guarantee optimal framework conditions for contract manufacturing.

Prototype construction

We have in-house development and construction facilities for prototype construction. Well-trained personnel use the modern equipped workshop and the electronics laboratory to develop new ideas for testing and production processes for the textile industry. In this way we offer the textile industry the opportunity to test and optimize at specially built test stands.

Please ask us!

DITF RESEARCH FIELDS

The DITF research fields have undergone a complete update as part of the strategy development. The new definition focuses on the markets and needs of tomorrow. It addresses the megatrends of global development and the associated challenges.

The previous six research fields, which focused on the entire production and value chain, have been reduced to five. research fields have been reduced to five. Since 2022, they have formed the thematic focal points in the DITF research portfolio, which the centers fill with life through their demand-oriented projects.

NEW MATERIALS

> Processing of natural fibers
> Biopolymers
> Biobased, biodegradable polymers and coatings
> Biocompatible biomaterials
> Oxide ceramic fibers
> Thermoset and thermoplastic matrices
> Low-cost, low-energy biobased carbon fibers
> Functional fibers (conductive, self-healing, sensory)
> Sound-absorbing and light-technical materials
> Flame retardants

LIGHTWEIGHT CONSTRUCTION

> Tailor-made textile fiber composites: braids, woven fabrics, nonwovens
> Multifunctional thermoset and thermoplastic matrix systems
> Nonwovens for thermoplastic composite
> (Continuous) fiber reinforced 3D printing, (braid) pultrusion, tape laying,
> 3D textiles for near-net-shape, adaptive and functionally integrated structures
> Fiber-based prestressed concrete
> Urban Textiles
> Component monitoring with integrated sensor technology

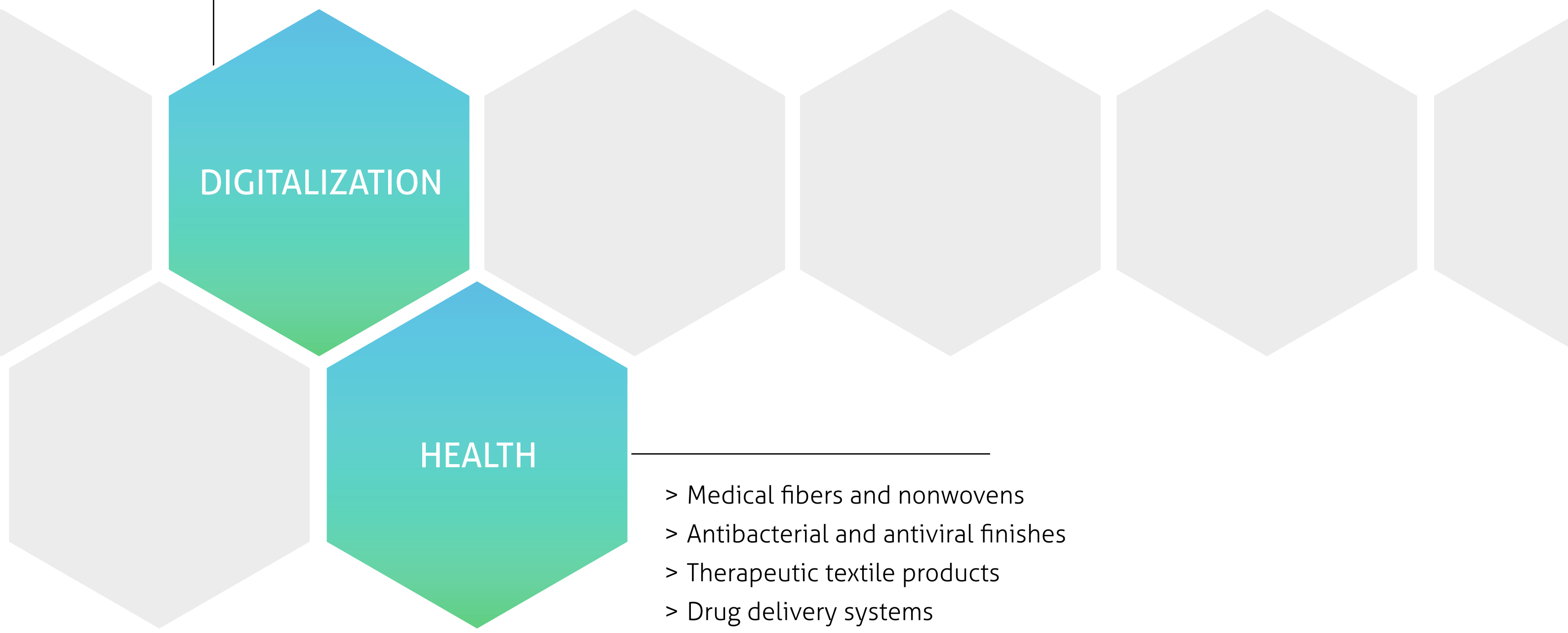
SUSTAINABILITY

> Single-variety composites
> Productivity increase and optimal raw material utilization
> Resource-efficient processes and procedures
> Energy generation through textiles
> Textile materials for biotechnology and environmental protection
> Holistic view of sustainability
> Circular economy
> Mechanical, thermal, chemical recycling

The revision of the research fields is based on research and takes a large number of studies into account that are relevant to the DITF. These include the BMBF's High-Tech Strategy 2025, the FKT Perspectives 2035, the innovation strategy and the State's coalition agreement, and many more.

At the same time, an analysis of the centers within the strategy process supported the classification into the new research fields. The current research topics can be precisely assigned to the newly selected research fields.

> Digital textile engineering
> Virtual testing
> Cross-scale modeling and simulation
> Digital material twins and process twins
> AI-assisted processes,
> Smart Home & Neighborhood
> Lot size 1
> Digitally networked production
> Sustainable and digital business models
> Socio-technical systems and value creation structures

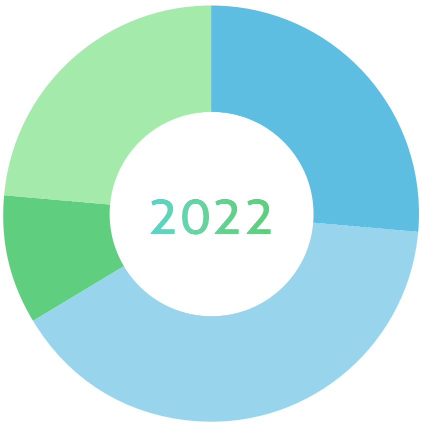


> Medical fibers and nonwovens
> Antibacterial and antiviral finishes
> Therapeutic textile products
> Drug delivery systems
> Theranostic systems
> Additive processes for individualized medicine
> Textile-based sensors and actuators, coupled with artificial intelligence (AI)
> Clinical and ambulatory health monitoring
> Personal protective equipment

THE **FUTURE** IS TEXILE!

FIGURES – DATA – FACTS

24.884 Total revenue



Revenues Industry:	6.618 TEUR
Revenues from public contracts:	9.932 TEUR
Other revenues:	2.492 TEUR
Institutional funding:	5.842 TEUR

(Income excludes ITV Denkendorf Produktservice GmbH)

In terms of industrial revenues, small and medium-sized enterprises play a particularly important role for the DITF. The share of SMEs in industrial projects in 2022 was approx. 67 %.

189 Public research projects

Subsidies from state, federal and EU programs. 25.0 % of revenue from public contracts in the reporting period came from the ZIM funding program, which is open to all technologies and sectors and aims to sustainably strengthen the innovative strength of small and medium-sized enterprises.

Employees as of 31.12.2022

DITF

219 employees
- 103 scientists* and engineers*
- 116 non-scientific employees

7 doctoral students
48 students (Bachelor and Master students)
42 % share of women

ITV Denkendorf Produktservice GmbH

39 employees

58 publications

36 of these in peer-reviewed journals

7 bachelor theses

15 master theses

13 dissertations

4 patents

Quality Management

Selected DITF laboratories and the testing laboratory of the ITV Denkendorf Produktservice GmbH are accredited according to DIN EN ISO/IEC 17025:2018.

The production areas filament yarns, needle felts, coated PP monofilament and the development areas of the DITF in the regulated area of medical devices as well as the ITV Denkendorf Produktservice GmbH are certified according to EN ISO 13485:2016. Scope: Design, manufacture and distribution of absorbable and non-absorbable polymers, fibers, films and membranes, surgical sutures, implants, wound dressings and anti-microbial meshes.

NETWORKS AND COLLABORATIONS

Networks help us to drive innovation faster and to operate more successfully in the market. For that reason, we actively promote networking and collaborations – across industries, nationally, and internationally.

Combined expertise

In addition to having close links to the business and science community, the DITF are intimately involved in the activities of a wide range of associations, organizations and thematic networks of excellence, which serve as a platform for cross-system, interdisciplinary research.

Applied research

One crucial task of the DITF is the support of SMEs through applied research together with the successful transfer of technologies. Networking and collaboration with other business-related research institutes help to reinforce the mid-tier research capacity in Germany. Accordingly, the DITF engage with the most significant research communities concentrating on industrial research at the state and federal level.

innBW INNOVATIONSALLIANZ BADEN-WÜRTTEMBERG

The DITF are part of the Innovation Alliance Baden-Württemberg (innBW), a group of 10 non-academic, business-related research institutions with a total of 1,500 employees. The institutes carry out result-oriented contract research in areas relevant for the future of the state. With around 4,600 industry projects per year, the innBW is an important partner, particularly for SMEs.

ZUSE-GEMEINSCHAFT

The DITF co-founded the German Industrial Research Foundation Konrad Zuse e.V. This association represents the public interests of non-profit industrial research institutions in Germany and is open to all technologies and sectors. Its members include independent research institutions from all over Germany. They promote innovations in all sectors, from agriculture to medicine to mechanical engineering and shipbuilding.

FIELDS OF APPLICATION

We encounter the textile world everywhere. Textile development and products are the key to innovation in many important industries and high-tech sectors. Fiber-based materials are among the most important materials of the 21st century. Multi-functional, cost-efficient and sustainable, they are recommended for more and more fields of application. We have carried out diverse research projects for industrial as well as public clients in the following fields of application:

Architecture and construction

Construction materials with textile components, fiber-based materials

Energy, environment and resource efficiency

Energy technology, environmental technology (e.g. water treatment, geo- and landscape protection, recycling of high-performance fibers), intelligent energy management

Health and care

Textile implants and regeneration medicine, wound treatment products, diagnostic and monitoring systems, smart textiles, depot and therapy systems

Production technologies

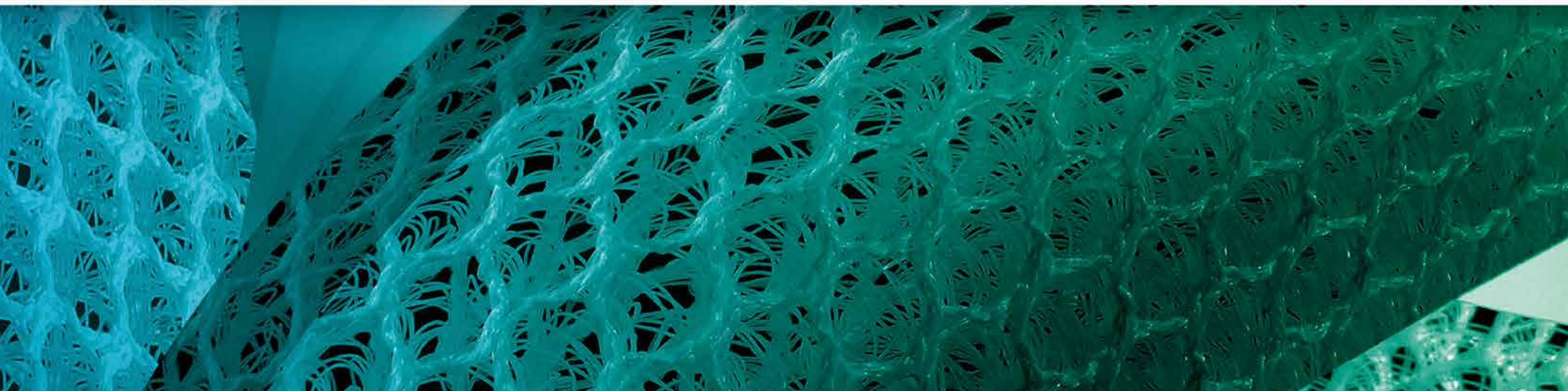
Process engineering and technology for higher productivity, quality and energy efficiency, automation

Mobility

Fibers, structures and products e.g. for the automotive industry and for aviation and space travel technology

Clothing and home textiles

Functional clothing, climate-regulating textiles, light textiles, sound technological textiles, smart textiles



ARCHITECTURE AND CONSTRUCTION

Fiber-based materials and processes for the construction of tomorrow. Innovations for more aesthetics, sustainability and functionality. For temporary and permanent buildings.

- Textile facade elements: intelligent, lightweight building shading
- Light directing textiles
- Acoustic textiles
- Intelligent, textile construction elements
- Pneumatic and hydraulic textile actuators
- Autonomous Living Wall Systems
- Textile moss walls for fine dust reduction
- Optically transparent, fiber-reinforced materials
- Textile solutions for smart homes and smart neighborhoods
- AI in the construction industry
- New textile materials for construction

Architecture and construction

The search for new solutions against the upheavals in energy supply accompanied by rising energy prices together with changed living situations due to the Covid 19 pandemic defines the future tasks in construction. Sustainable, affordable and attractive solutions must be found that make the energy transition climate-neutral in both urban and rural areas and that take into account the changed living situations in the context of home offices and homeschooling. The DITF are therefore developing textile solutions for smart neighborhoods, for improving air quality, for avoiding urban heat islands, for rain retention, for optimizing resource use, and for recycling. The unifying objective is to shape the challenges in the construction industry qualitatively and socially for people.

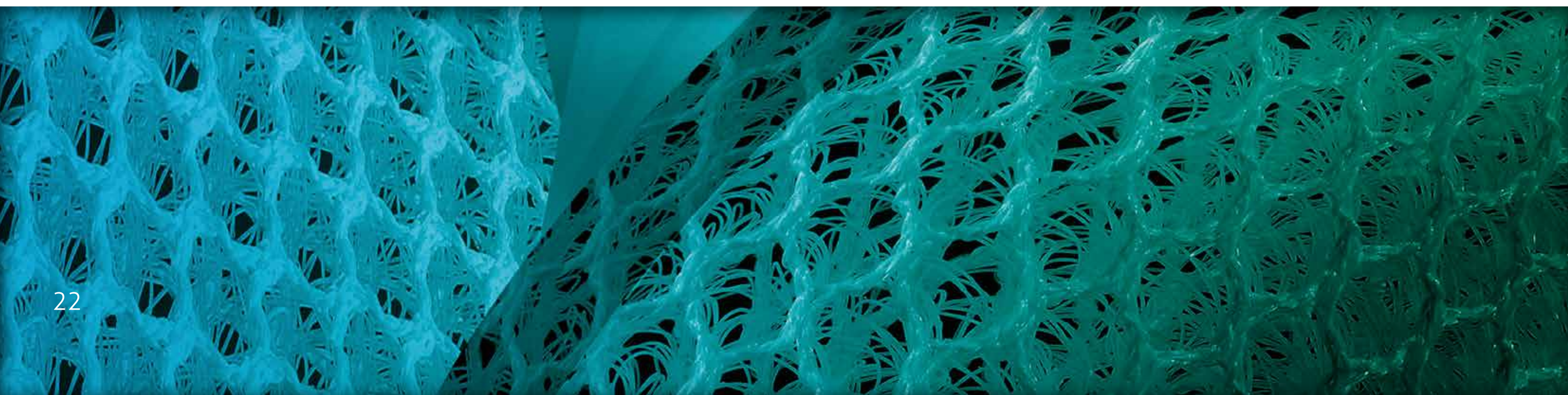
Functional, smart building textiles

The DITF develop new textile materials, structures and control systems to meet these future challenges and to create new parts, components and products for the entire field of construction. The focus here is on integrated solutions. For example, protection against climatic influences is often coupled with new solutions for sound and light. The increase in weather extremes such as heavy rain also places new demands on construction. But more green in cities also increasingly requires more intelligent and efficient use of water as a resource in construction. New materials and building elements must fulfill static, energy and design functions in the context of sustainability. It is precisely in the case of such multiple demands that fiber-based materials show their strengths. In combination with AI solutions, this potential opens up for the user. In this way, these solutions can help to make the current renovation of existing buildings more economical and at the same time leverage energy potential. Both of these factors directly support the quest for affordable housing. In this way, functional, smart building textiles make a concrete contribution to strengthen the social component in future construction.

Textile redensification solutions

An important step for the transfer of building textiles and concepts into application is development and validation in the real laboratory. Ideas can be developed and new approaches tested and demonstrated at the Denkendorf ResearchCUBE, leading the to rapid implementation in products. New shading textiles create a lighting situation in the interior that, despite reduced glare, directs so much valuable daylight into the room that artificial lighting can be dispensed with. Integrated textile sensors measure the illuminance and control AI-supported textile-based actuators that adjust the shading depending on the position of the sun. These textile AI solutions can not only be used in the smart home, but also open up further possibilities in the area of smart neighborhoods. Here, tasks are no longer addressed in the individual object, but are solved in the intelligent networking of several buildings and with external knowledge. The focus of research here is on issues relating to energy generation and use, as well as (drainage) water management in the face of increasingly sealed surfaces.

The facade of buildings provides another great potential for solving issues of redensification. Textile facade systems can be designed to be lightweight, flexible and



more functional. Attached vertical greening systems (living walls) not only promote the quality of air and life in densely built-up inner cities, but can also be used in urban water management thanks to their controllable water retention capacity and, if used intelligently, reduce the heat island problem. Textile roof structures in the form of membrane structures have also long since found their way into permanent buildings. For example, textile materials offer roofs for stadiums, train stations and airports greater versatility than almost any other material thanks to their flexibility and low weight.

Fiber composites in construction

Against the backdrop of global growth and limited raw materials, decarbonization and a significant reduction in the consumption of mineral materials are key tasks for the future of construction. For this reason, fiber composites are also becoming increasingly important for use in construction. They open up new possibilities with industrially relevant property profiles due to their high specific strengths and stiffnesses. The material properties can also be tailored to a wide range of applications thanks to the fiber orientation, fiber-matrix adhesion and the many possible combinations of fibers and polymer matrices. The incipient digital transformation of everyday life and industry increasingly requires complex materials that, in addition to their usual inherent characteristic values, have additional features such as artificial "sense organs" in order to survive in an increasingly networked environment. The DITF develop feasible and efficient solutions for this.

Textiles as acoustic design elements for living and working in the future

Driven by redensification processes as well as by changed living situations within the context of home office and homeschooling, the modern world is characterized by increasing noise pollution. Urbanization, redensification and high traffic volumes require sustainable and efficient acoustic design solutions both in the living environment and at work. The intrinsic properties of textiles, as well as the possibility of creating novel acoustic effects through textiles, make textile sound absorbers and attenuators essential in the building sector. Textiles themselves offer the potential of sustainable and resource-efficient management of noise problems and are thus innovation drivers for many construction sustainability issues such as lightweight construction. All in all, textiles pave the way to a healthy, sustainable and economical future for the human habitat.

Rain-retaining Living Wall enables redensification with flood protection

Against the backdrop of growing redensification in inner cities and the resulting increase in sealed surfaces, green facades not only offer an opportunity to bring more green into cities. By integrating textile storage structures, additional volume is created for the retention of precipitation. In this process, the water flow is controlled by novel hydraulic textile structures. In combination with textile sensors for recording the water and nutrient content in the plant substrate, the Living Wall can be operated largely autonomously with little maintenance and care. Depending on the amount of precipitation, rainwater can thus either be accumulated in a textile structure for water storage or discharged into the sewage system with a time delay. In this way, facade greening enables redensification, while at the same time efficiently using the resource water or temporarily storing it in the event of heavy rainfall in the sense of flood protection.

Rain-Retaining Living Wall

Research on this topic also includes
> the scientific investigation of the cooling capacity of a facade greening through transpiration of the plants,
> the development of a textile-technological innovation for evaporation and
> modeling for cost-benefit calculation and life-cycle analysis.

Based on laboratory and outdoor investigations, a new evaluation basis for green building systems in general has been created in the form of a green value.

Acoustic camera makes sound sources visible

In the context of acoustic research, the question arises: "Where does sound come from and where does it go?" Where the human ear can make a rough estimate of the localization and directional characteristics of sound sources thanks to binaural hearing, metrological determinations are only able to specify the sound source in more detail with great effort. For this purpose, a virtual sphere is stretched around the measurement object and a large number of the surface points are analyzed for the local sound level. This allows conclusions to be drawn about the radiation characteristics of the object under investigation.

The use of a so-called acoustic camera makes this procedure unnecessary in most cases. The sound source is localized directly on the camera via a specific arrangement of microphones. At the same time, the source location is superimposed on the real image in the camera. By variable restrictions of the measurement window, the spatial resolution of the sound origin can be limited to a few centimeters. The spatial mobility of the camera also allows a qualified statement about the radiation characteristics. Thus, it can be determined in which direction the majority of the sound energy is emitted. Time-resolved measurements also allow reflections from objects to be displayed, and it is possible to investigate the propagation of sound waves in space.

Sound sources can thus be attenuated in a resource-efficient manner, since only the source location needs to be attenuated, and unwanted reflections can be avoided by means of absorber structures. The acoustic camera has become an essential development tool for acoustics at the DITF.

Absorption effect of the ecological absorber panel of the DITF shown by means of an acoustic camera

Cold-curing high-performance ceramic composites for the construction industry

Cement and concrete production is a significant source of global greenhouse gas emissions. Reinforcing concrete with plastics reinforced with glass, basalt or carbon fibers can significantly reduce material consumption, construction material costs, construction time, weight, wall thicknesses as well as greenhouse gas emissions and waste generation.

Due to the corrosion resistance of the composites, much less concrete cover can be used. Compared to reinforcement with steel, this results in an up to 80 % reduction in concrete consumption with a corresponding reduction in the weight of the trades.

The possible applications of fiber-reinforced composites as concrete reinforcements have so far been limited mainly by the relatively low temperature resistance of the organic matrices (< 200 °C) and their flammability or fire behavior. One way of exploiting the aforementioned advantages of textile composites in construction and meeting fire protection requirements is to use fine concrete systems or so-called inorganic "chemically bonded ceramics" (CBC) matrices such as water glass systems or phosphate ceramics.

Basal roving, CBPC matrix, pultruded profiles and wound sheet

In the AiF project NiBreMa, a new phosphate ceramic matrix was developed, which in its initial state is in the acidic pH range and thus does not attack the E-glass or basalt fibers, which offer economic advantages over carbon fibers. For this approach, DITF together with DLR investigated both matrix and process development. The resulting cold-cured basalt fiber-reinforced composites exhibit good mechanical properties and compatibility with Portland cement concrete.

New ways to utilize the waste material lignin

Along with cellulose, lignin is a major component of wood and is produced in large quantities as a waste material during paper production. Research projects at the DITF are currently investigating how this lignin can be used to produce novel textiles with special properties. In particular, the combination with natural fibers is the focus here, as this can be used to produce high-quality and, at the same time, completely biodegradable composite materials. In the projects, the processing properties of the lignins are improved, especially by thermoplastic processes, and the application-related properties and biodegradability of the materials are determined.

Coating of a cellulose nonwoven with lignin

Textile coated with lignin in 3D-printing

Coating and 3D-printing on textiles

Trials with lignin for yarn and surface coating showed very positive results. Lignin coating significantly extends the life of textiles made of natural fibers for geotechnical applications, as shown by laboratory and field degradation tests. Thanks to the lignin coating, they have a long, adjustable life span, but at the end of this life span they are still biodegradable and can thus replace some synthetic materials used so far. In another project, the processing of lignins in thermoplastic 3D-printing processes is being researched. The structured coatings applied to textile substrates take on special barrier functions.

Textiles coated with lignin have the potential to significantly reduce the carbon footprint, reduce dependence on petroleum-based products, and reduce microplastics in the environment.

HEALTH AND CARE

Textile materials, products and processes for innovative fields of application related to human medical care.

- > Resorbable polymers and bio-materials
- > Implants
- > Cell carriers for regenerative medicine, biohybrid organs
- > Additive manufacturing, micro injection molding
- > Sensory textiles
- > Personalized orthotics
- > Wound dressing materials
- > Bioactive coatings, e.g. for wound dressing
- > Drug delivery systems: Drug capsules and porous fibers
- > Antibacterial and antiviral textiles
- > Textile-based surgical instruments
- > Hospital and surgery textiles
- > Biological testing on implants, barrier textiles and clothing

Health and care

The last pandemic is largely behind us, restrictions have been lifted, and yet our healthcare system remains at its breaking point. For medical device manufacturers, the picture is mixed: While manufacturers have benefited greatly in areas such as critical care and vaccines, others are still struggling with declining orders as a result of postponed surgeries and treatments due to capacity constraints and staff shortages. In addition, there is the massive burden of the new Medical Devices Regulation, which also means a considerable effort with currently extended deadlines for recertification until the end of 2027 (for higher-risk products) or the end of 2028 (for medium- to low-risk products).

Nevertheless, the DITF continue to register great interest from companies that want to take advantage of their many years of experience in the field of medical device development and likewise its high level of expertise in the development and evaluation of products to defend against bacteria and viruses. In addition to projects on protective equipment, the focus is often on sensory textiles in the broadest sense, which support patients in their therapies, but also on the functionalization of existing products to improve the success of therapies as well as individual adaptation to the patient.

Biofeedback using smart textiles

Many therapy concepts today increasingly involve the patient himself or herself to maintain abilities or regain lost abilities of the body in specially developed training programs.

Within the "Go, WannaGo!" project of the International Sports Innovation Network (SINN-i), the target group of so-called "WannaGos," who make up about 55 % of the population and are characterized by an interest in health well-being – but a lack of physical activity – is motivated to lead a more active and healthier lifestyle. The Joyification concept encourages exercise by combining elements of gamification, music, and cooperation. To this end, input devices are being developed and tested at the DITF based on various forms of sensorized polymers that function in themselves or as part of fitness and other equipment. Together with a new sensory mat, engineered solutions tailored for the WannaGos are being investigated and marketable solutions are being prepared.

Digital functionalization processes for textiles

Functionalization is a key issue not only for classic textiles, but also for all medical devices. For example, antiviral printing inks can be used in digital printing technologies, reducing chemical consumption and finishing set-up times in small production runs or for customizable products. Thanks to the highly flexible application processes and specially adapted inks, applications with localized and thus cost-effective functionalization of textiles are possible.

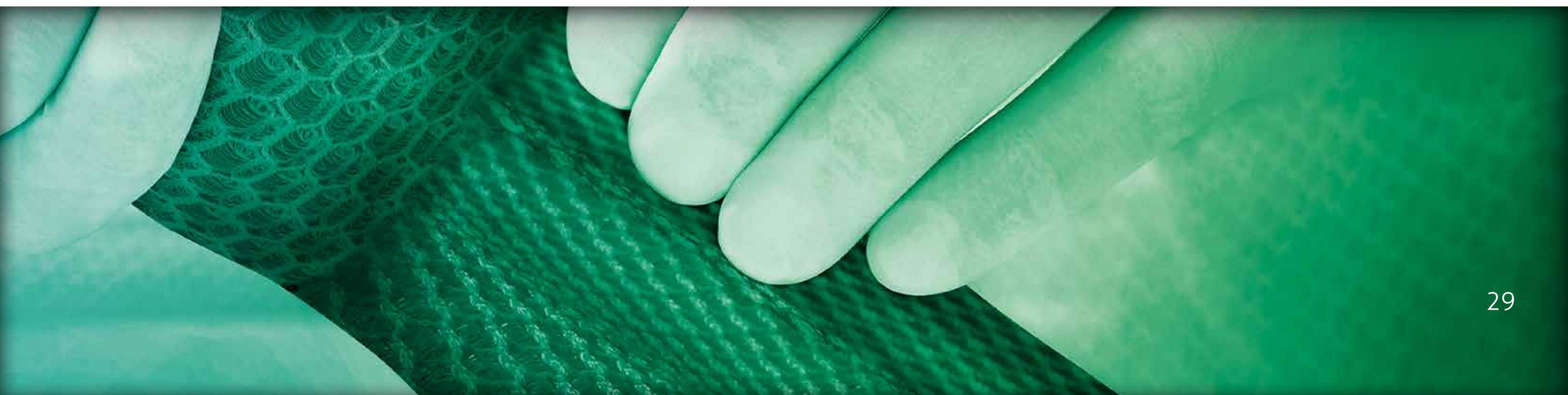
Reduce germ and particle contamination of operating fields

Textiles ensure protection against germs and can also significantly reduce the risk of injury at work or during many recreational activities. But what happens when the body surface must be opened for surgery? Infections with hospital germs, known in technical jargon as nosocomial infections, arise from contamination of surgical wounds with multi-resistant germs and can lead to complications that are difficult to control. Together with our industrial partner, we developed a textile ventilation tube that uses purified air to shield pathogenic germs from the area underneath. A specially developed test with nebulized colony-forming germs impressively demonstrates its effectiveness.

Individualized medical technology

A new type of foot orthosis for the treatment of patients with cerebral palsy and associated motor impairments is being developed at the DITF in a cooperative project. In the so-called Textile Dynamic Ankle-Foot Orthosis, biomechanical posture and movement control is achieved with a textile orthosis instead of complex manually manufactured, rigid plastic shells. The footbed, which is directly integrated into the textile, can increase wearer comfort and acceptance, provide improved proprioceptive stimulation of trigger points, and be custom-made for young patients. The manufacture of custom products in particular offers opportunities and business segments for small and medium-sized companies in medical technology, since although the MDR must also be complied with for patient-individualized orthoses and implants, different rules and responsibilities apply here in some cases. One of the most serious consequences of the new Medical Device Regulation, the massive streamlining of product portfolios due to the high costs of re-registration, can thus be mitigated. In particular, products with low sales, which especially concerns the treatment of children and rare diseases, can continue to be offered in this way.

The DITF are excellently positioned in medical technology. For more than 40 years, fiber-based medical products have been researched and developed here on an interdisciplinary basis, from polymers to implants or hospital textiles. They offer the entire spectrum of innovative medical device development, from polymer development to biomaterial processing and functionalization to prototype production. This also includes cell biology and microbiology testing for function in vitro. The DITF's Biomedical Engineering Development department and its subsidiary, ITV Denkendorf Produktservice GmbH (ITVP), are certified according to: EN ISO 13485:2016 by BSI UK for design and development as well as production and distribution of absorbable and non-absorbable polymers, fibers, films, membranes, implants and wound covering materials as well as antimicrobial meshes.
This makes it possible to manufacture prototypes in the clean rooms of the DITF and ITVP that may be implanted directly into humans. If desired, the ITVP also provides its production capacities from the molecule to the nearly finished medical device and offers the execution of research, development and production orders according to current legal requirements and with documentation in conformity with the approval.



Digitally controlled functionalization process for textiles

Textile materials are traditionally functionalized by impregnation with finishing chemicals in a padder or by coating and screen printing. Such processes are generally designed for large orders and, with small batch sizes, lead to very high chemical consumption as well as long set-up and cleaning times. Digital and highly flexible application processes that enable cost-effective and targeted local functionalization with minimal chemical consumption are therefore increasingly in demand.

Digital functionalization and finishing

The DITF have developed the basic principles for the digital functionalization of textiles by means of digital printing and have worked out optimum printing parameters for the application of functional inks with inkjet and chromojet. Due to the larger print nozzle diameter, the chromojet process offers advantages in terms of simpler ink formulation and higher ink add-on. The functional inks were essentially built up from functional chemicals or from functional particles and binders and adapted to the print head by adding additives. Inks for hydrophobic and antistatic finishing as well as functional inks with fluorescent and electrically conductive properties could be realized.

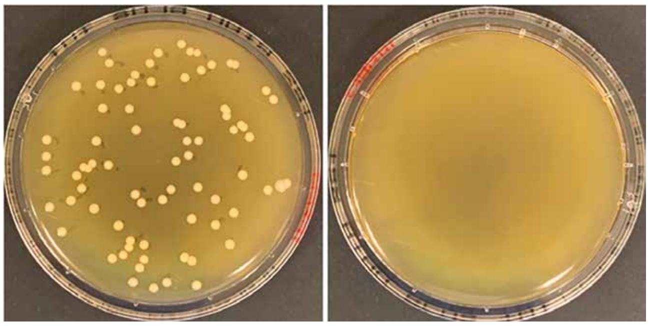
As an absolute novelty, a pH-triggered, foam-forming ink was also formulated. Medical applications are also possible and were demonstrated using the example of an antiviral ink.

Foam formation through functional inks

Pleated textile tube for the ventilation of surgical fields

Nosocomial infections, also known as hospital-acquired infections, result from microbial contamination of surgical wounds and can lead to severe complications. On behalf of Wandres GmbH micro-cleaning, the Technology Center Biomedical Engineering at the DITF developed an air-flow ring tube, the Airflow Ring, which reduces the risk of contamination. By feeding HEPA filtered air through the Airflow Ring, it was shown that pathogenic germs are shielded from the zone below.

Airflow Ring for the ventilation of a surgical field



Tests with colony-forming germs: unventilated on the left, ventilated on the right

The radial stability combined with high flexibility was achieved by pleating a knitted polyester tube. The partial coating on the outer side (see Fig., purple coloring) directs the ventilation zone to the inner area of the ring. A line of bio-compatible adhesive on the underside fixes the Airflow Ring to the skin, so that it is in close contact to the skin, on curved parts of the body, such as joints. This prevents the penetration of air and thus germs between the skin and the tube.

The functionality of the ventilation tube has been successfully proven by tests with nebulized, colony-forming germs.

Textile dynamic ankle foot orthosis

Together with the Dynamic Competence Center (Mühltal), the DITF are developing a novel foot orthosis with an integrated footbed for the treatment of patients with cerebral palsy.

Orthoses currently used for the treatment of infantile cerebral palsy consist of partially flexible plastic shells, which are very complex to manufacture by hand and have to be adapted precisely to the patient's foot. A digital manufacturing process is to replace the previously expensive and error-prone manufacturing process. The newly developed orthosis replaces the plastic shell with a close-fitting stocking that completely encloses the foot and ankle and provides sensory-motor stimulation. The alignment of the joint chain starting from the foot is achieved by means of a modularly integrated, individual foot bed and the special cut construction of the stocking. Correct alignment of the foot in combination with increased proprioceptive stimulation of trigger points enables improved biomechanical postural and movement control in patients with limited body awareness. In addition to functional improvements, the textile orthosis is expected to increase wearer comfort and acceptance compared to the plastic orthosis.

Ready-made compression stocking, 3D-printed sole

Go, WannaGo! Elastic band for rehab and sports with sensor integration

Developments in the field of textile sensors have increasingly come into focus at the DITF. Areas such as fiber composites but also the monitoring of vital parameters are only a part of the diverse fields of application. The field of health and care will concern us all at some point in the future and is therefore becoming increasingly important. In times of home office, people lack more and more movement due to the advancing digitalization, whether at work or in private life. The "Go, WannaGo!" project aims to motivate people to move more. Our society consists of three categories of movement types: the "GoGos," who already have an intrinsic motivation to move, the "NoGos," who have no motivation to move, and the largest group, the "WannaGos," who would like to move but don't for a variety of reasons.

Schematic representation of a company case

The "WannaGos" are the target group addressed in this project. The fun factor in the new exercise concepts is intended to motivate the "WannaGos" to move more and in a targeted manner in their professional and social environment as well as in rehab, thus promoting their health. The elastic band developed at the DITF based on the piezoresistive principle and a sensor mat are to provide support here and make movement visible and/or audible in cooperation with the members of the consortium. This "joyification" of movement can be achieved and promoted in a targeted manner by means of pressure- and tension-dependent detection of movements.

More details about the project and the consortium at www.sinn.international.

MOBILITY

Textile innovations from the DITF in the field of lightweight construction/fiber composites are helping to shape the mobility of the future and offer solutions for reducing emissions, conserving resources, comfort and functionality.

> Increasing use of natural fibers, bio-based fibers, bio-matrices and aggregates. Implementation of the NATURALfiberEXTRACTION congress

> Cooperation with V-Carbon for the production of high-quality semi-finished products from recycled carbon fibers for loadbearing components

> Co-Organizing the 5th Carbon Recycling Congress in Stuttgart

> Reduction of the carbon footprint through carbon fibers made from cellulose, lignin and chitin in combination with energy-saving kiln technology

> LCA knowledge of the entire textile processing chain

> Simulation of Manufacturing process and component behavior to reduce costs and extend service life

> Micro-computed tomography for the detection and elimination of component defects

> 3D Space Wrapping and Tape Laying for Ultra-Lightweight Construction

> Complex woven ceramic fiber preforms for Ceramic Matrix Composites (CMC) with high stiffness and thermal cycling.

> Cellulose-based filter materials and economical and ecological materials for fuel cells

> Smart, resource-saving, textile solutions for interior lighting, heating, operation, safety and security

> Energy-saving production technologies, e.g. use of UV technology

Mobility

The framework conditions for mobility are constantly changing, e.g. electromobility, tightening of exhaust regulations/CO_2 pricing, future fuels, safety for all road users and connectivity/ communication.

Due to the increasing environmental awareness of people and the politically pushed bioeconomy, an ecological, social, economically justifiable change is to be brought about. This brings lightweight design and resource efficiency back into focus. Life Cycle Analysis and other tools provide information on CO_2 emissions from raw material to end of life along with data for recycling materials or products, thus helping to conserve resources.

Sustainable materials

Steel and aluminum are still used for load-bearing components in cars and railroads, while unreinforced or short-fiber-reinforced plastics are used for semi-structural or low-load components. Advantages include price, good mechanical properties, proven calculation methodology and processability, high recyclability and worldwide availability. However, if the weight of the vehicles is taken into account – which directly correlates with the level of CO_2 emissions – the lighter, continuous fiber-reinforced plastics (FRP) are advantageous, also because of their excellent crash behavior. FRP are already being mass-produced for body parts. In hybrid construction, the advantages of the respective materials in terms of cost, ecology and recyclability are contrasted in what is known as hybrid construction. Each material or combination of materials is used in the most suitable place in the overall component.

Since petroleum-based high-stiffness/high-strength carbon fibers have a high global warming potential, carbon fibers made of cellulose, lignin or chitin are produced at the DITF. As a partial substitute for glass and basalt fibers, cellulose fiber and natural fiber composites are being developed at the DITF and qualified for their use in mobility. With appropriate use of resin systems and adhesion promoters, similar high strengths to glass fiber composites can be achieved. The sustainability of the bio-based materials is demonstrated by a comprehensive LCA assessment of the specific global warming potential and leads to essential insights for further developments in the field of polymer synthesis and process engineering.

Computer-aided design and manufacturing, PLM systems, digital twins

In contrast to metals and plastics, the CAM chain is less well established for FRPs. Material data for component design, such as (fatigue) strength, stiffness or joining options, are much more complex to determine, since, for example, small changes in fiber angles generate new mechanical component properties and result in unintended higher component weights. Nevertheless, the aim is to further improve the CO_2 balance by further reducing material and energy consumption. Most importantly, consideration of possible closed-loop recycling is also included in the product development phase. The bioeconomy is supported and proven by the establishment of a comprehensive life cycle assessment. The continuous computer support and the creation of digital twins support the acquisition of the necessary data.

By means of the computer tomograph established at the DITF, parts or components can be examined down to the smallest structural level. Thus, weak points such as microcracks, missing fibers or fiber misalignments can be detected, also enabeling an optimal guidance of the fibers with maximum utilization of their strengths.

Topology optimization

In addition to the classic textile techniques like non-crimp-fabrics, weaving, braiding and nonwovens, the DITF are increasingly using material- and cost-saving processes such as wet winding or TowPreg winding and tape placement, which generate very little waste. Improved alignment of the load-bearing fibers in the direction of the force flow lines makes better use of the material. Both lightweighting measures improve the LCA, reduce the consumption of drive energy – for example, also the abrasion of tires, brake discs and brake pads – and thus also reduce the amount of microplastics. A BMW M4 lightweight center console manufactured at the DITF using winding technology, among other things, won the highly regarded global lightweight construction "Sustainability Award" from the Altair company.

Component monitoring and function integration

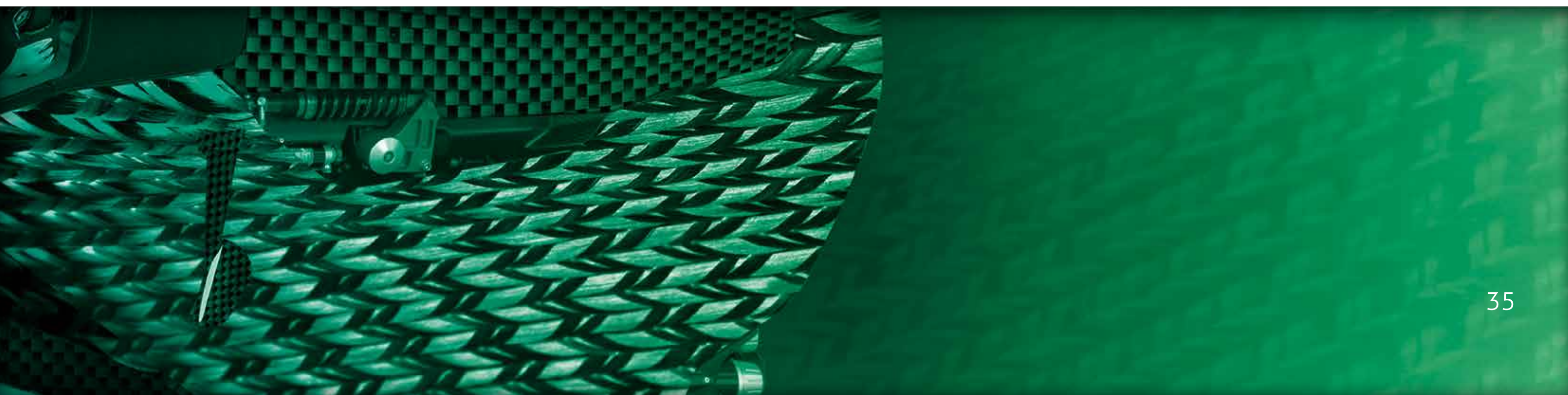
Textiles enable functional integration, e.g. embedding of sensors, heating / lighting elements or actuators in the fiber composite. Textiles reinforce injection molded components like connectors or solid joint hinges. Textiles integrated sensors enable component monitoring without the need for costly added-on sensor technology.

Recycling and closed-loop control

The recyclability of components and materials is crucial for improving the cost-effectiveness and sustainability of FRP. Residual fibers, textile offcuts, prepregs and end-of-life components must be recycled or recirculated in an environmentally friendly manner. Only with a high recycling credit can the materials exploit their lightweight construction potential. Together with the fiber composite and recycling specialists at the DITF, proven experts from the DITF's Management Research department are working on the determination of key sustainability data (e.g. Global Warming Potential GWP).

Fire protection

Thermoplastic matrices such as PA6 with high flame retardancy (LOI of 34-36!) have been developed at the DITF. This PA6 could even penetrate areas, which were previously reserved for much more expensive matrices like PEEK and PSU. In the area of cellulose and natural fiber composites, an excellent fire class B1 could even be achieved through a combination of internal and external additives. The DITF are also conducting research into low temperature curing ceramic matrix systems. Concrete reinforcing bars (rebars) with a ceramic matrix stable up to 1,200 °C are already being successfully produced by pultrusion.



Cyclometric project – Circular economy for textiles in automotive engineering

The circular economy in automotive engineering requires a systematic and holistic view of materials and processes over the entire life cycle of vehicles. The Cyclometric project, which is funded by the BMBF and supervised by PTKA, takes up this topic and aims to develop a holistic material and utilization concept that engineers can draw on as early as the development of functions and the selection of materials.

The CYCLOMETRIC tool is designed to ensure that all components are recyclable already during development

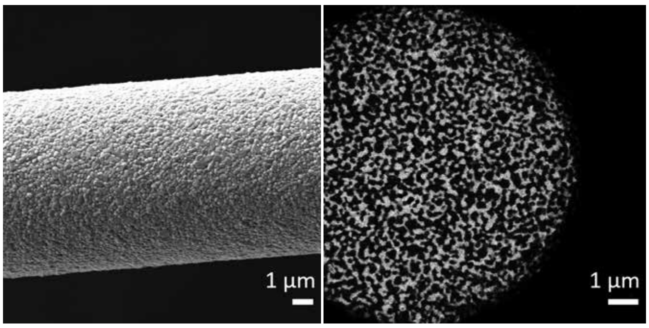
To develop a closed-loop concept for textile elements in vehicle interiors, the DITF, Fraunhofer IAO and IBP, the University of Stuttgart, the Business School of Reutlingen University, Schweizer Design Consulting, Forward Engineering, IILS Ingenieurgesellschaft für Intelligente Lösungen und Systeme, DXC Technology Deutschland and the Lotus Tech Innovation Centre have joined forces to form an interdisciplinary project team. The project partners are developing an exemplary modular smart mid-arm console, which will be used to demonstrate the concept of a closed-loop capability for materials.

In the process, various approaches are being tested that could be considered for the closed-loop recycling of textiles. First, textiles can be made from recycled fibers sourced from other industries. Second, textiles can be designed to be recyclable, i.e., made of single-origin fibers or easily separated. As a third option, modular textile elements for vehicle interiors could be offered under rental or leasing models to extend useful life and facilitate take-back.

Aerospace applications of oxide ceramic fibers with new compositions

The fact that the DITF have been working on the research and development of oxide ceramic fibers for decades is now well known. Last year's annual report reported on the cooperation with Saint-Gobain, which involves the industrialization of the Denkendorf technology. Parallel to this, research activities continue to be carried out with the aim of further increasing the temperature resistance of oxide ceramic fibers. While the previously known fibers made of aluminum oxide and mullite, depending on their composition, exhibit long-term resistance to temperatures between 1,000 °C and 1,150 °C, a further improvement in temperature resistance is being sought above all in high-tech applications in the aerospace sector.

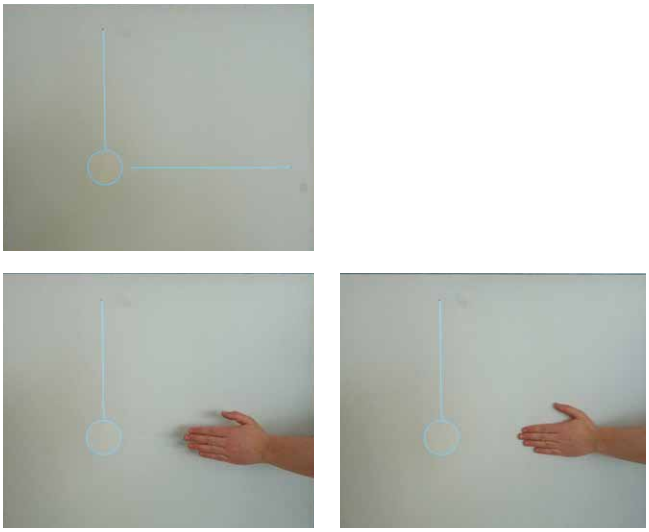
There, the aim is to replace metallic superalloys, which can also be used up to temperatures of 1,100 °C – but only with appropriate cooling. If the long-term temperature limits for oxide fibers and the ceramic composites made from them can be raised to 1,200 °C or 1,250 °C, this would represent enormous technical progress. Current developments at the DITF are therefore concerned with the multiphase systems AYZ (Al_2O_3, Y_2O_3, ZrO_2) and ASZ (Al_2O_3, SiO_2, ZrO_2), which have the potential to shift critical processes such as creep deformation and undesired grain growth to higher temperatures. One example of these new fiber types is the production of fibers containing the extremely creep-resistant YAG (yttrium aluminum garnet) in addition to aluminum oxide.



Oxide ceramic fiber with a composition of 50 wt % alumina and 50 wt % yttrium aluminum garnet: surface structure and phase distribution in cross section via BSE electron microscopy

Textile gesture recognition and control

Sensory wrapping yarns enable textile products with novel functions. At the DITF, location-sensitive yarns are being developed that only need to be contacted on one side and with which the position of the finger on a yarn can be detected. Several of these yarns can be used to produce two-dimensional touchpads, which also only need to be contacted on one side. This technology enables textile gesture recognition with completely new possibilities. It is possible to recognize proximity, motion and wiping gestures. A wide range of novel applications can be addressed, for example in the fields of smart home, mobility and workwear. This enables highly functional textile control elements.



Demonstrator with textile gesture recognition and optical feedback

By using wrapping technology, the yarns with their textile properties can also be processed with conventional textile production technologies. By means of electroluminescent, luminescent yarns, feedback can be provided to the user via touch. For example, the triggering of a switching function can be visualized and indicated by such yarns lighting up. Luminous yarns can additionally be used for ambient lighting functions and can glow in different colors by supplying electrical energy. Complex man-machine interfaces offer the user completely new product possibilities through the combination of the two technologies.

UrbANT project: Micro-transport systems for the last mile

The combination of public transport and individual transport can cover a large part, but not all, of inner-city mobility needs. There is a gap that can be closed in a sustainable and future-oriented urban mobility offer by suitable micromobility solutions.

To this end, an autonomous, electrically driven micromobility vehicle was developed as part of the BMBF-funded project "UrbANT" (Urban, Automated, User-Oriented Transport Platform), which enables pedestrians in particular to transport heavy and large-volume goods safely and comfortably.

Fiber composite solution

In the project, the DITF designed and developed a flexible and height-adjustable body for the vehicle. In addition, the DITF supported the design of the drive platform and other body variants. For this purpose, the individual components of the body structure were manufactured by means of vacuum bagging, winding and tape laying processes with subsequent hot pressing.

To meet the lightweight requirements and increase the payload, ergonomics and variable useful volume of the vehicle, a telescopic body structure was manufactured in fiber composite sandwich construction. Electronic components such as the display, user interaction modules and automated driving assistance components were integrated into the roof or floor modules. The functionality of the UrbANT was tested in various operational environments.

UrbANT Demonstrator

ENERGY, ENVIRONMENT AND RESOURCE EFFICIENCY

The DITF develop processes and systems for greater energy, environmental and resource efficiency with and for their industrial partners. This results in sustainable products and services for a wide range of applications.

- High-performance fibers from biopolymers
- Carbon fibers from cellulose and lignin precursors
- Sustainable polymer syntheses to replace petro-based monomers
- Coatings and finishes made from renewable raw materials
- Environmentally friendly pulping processes for natural fibers
- Cellulose-based nonwovens for CO_2 absorption from the air
- Pure, sustainable single-component composites
- Solvent-free, energy-saving processes for coatings and textile finishes
- Minimal application technologies (foam, plasma, 100 % systems)
- Use of AI for parameter setting of equipment machines
- Textile-based thermal solar collectors
- Energy generation through the use of technical textiles
- Economic and ecological materials for the fuel cell
- Textile materials for drinking water recovery from mist and industrial aerosol separation
- Irrigation systems based on particularly high capillary forces and suction stresses
- Filter materials for gas/solid/liquid separations
- Recycling technologies for highperformance fibers and coated textiles
- Analysis of biodegradation in water and soils

Energy, environment and resource efficiency

Since time immemorial, fibers have been crucial building blocks of nature. Particularly in the plant kingdom, nature makes use of properties of fibers to build a wide variety of structures and functions. It is therefore not surprising that fiber-based materials have many convincing and sustainable solutions to offer for the requirements in the fields of lightweight construction, energy efficiency and energy storage, effective use of resources and environmental protection.

Due to the increasing importance of the research field of energy, environment and resource efficiency, the DITF bundle research capacities and know-how in two competence centers, the Competence Center for Biopolymer Materials and the Competence Center for Textile Chemistry, Environment & Energy. The DITF are thus an important research partner in this future field and develop processes and systems for greater energy, environmental and resource efficiency with and for its industrial partners. This results in sustainable products and services for a wide range of applications. Sustainable high-performance fibers, new biopolymer materials, filters and membrane materials for air and water purification, lightweight construction developments, insulation, sealing and insulating materials for buildings and textile-based solar cells are just a few examples.

Current research is primarily focused on substitution of petroleum-based materials, material efficiency, use of artificial intelligence, biodegradation and recycling.

Renewable energies, energy systems

The success story of technical textiles in Germany is based on the development of ever new fields of application. Particularly fascinating in this context is the generation of energy through the use of technical textiles. Intensive research is being carried out in this field at the DITF. Successes have been achieved in solar thermal energy and in the storage of thermal energy as well as in combinations thereof. There are further developments in resource-saving and also economical new materials for hydrogen technology and in new systems for the storage of electrical energy. Recent work has focused on safety and environmental aspects of solar cells, on the use of biopolymers, and on textiles for seawater desalination. The contribution of fiber composites for wind turbine rotor blades is also not insignificant.

Textiles for environmental protection

In the meantime, technical textiles are making a major contribution to the mastering of tasks for environmental protection in many branches of industry. Our research work in this area includes new filter systems, e. g. for the separation of fine dust and pollen from the air and for the separation of aerosols in cold and hot exhaust gas streams. In coupling with living organisms, we develop textile carrier materials for biological organisms in vertical greening, sewage treatment plants and algae production. To improve plant growth, novel irrigation and water storage systems for greenhouses and nursery systems are under development. Further development of sound absorption in home and mobile applications continues to be a research topic.

One focus for many years has been the application of membranes in wastewater treatment in the textile industry but also in the treatment of wastewater from other manufacturing plants.

Direct absorption and desorption of carbon dioxide from ambient air is made possible by newly developed filter materials based on nonwovens made from functionalized cellulose fibers.

Sustainable fibers and composites

The sustainability of textile products is a key issue for our society and is currently undergoing a strong collective change. In view of the discussion on microplastics, our research work on natural fibers and polymers made from renewable raw materials that are also readily biodegradable and/or recyclable is of forward-looking importance. For example, natural fibers from wood, hemp, nettles, lavender or algae play an enormous role in the production of textiles as well as their ecological and economic recycling. Lignin, until now a waste product in paper production, shows high potential in our studies as a coating for yarns and textiles and as a matrix in composite materials. Further work includes the processing of natural fibers into high-performance yarns as well as the development of new filter materials and composites from cellulose and also from chitin. For these composites, new reinforcing fiber types based on cellulose have been developed using HighPerCell® technology. These filament yarns are also suitable for the production of carbon fibers.

The production of cellulosic composites creates lightweight, stable, aesthetic products that can be recycled for materials or bioenergy and lead to an overall positive carbon footprint.

A fairly new branch of bionic developments involves self-healing materials that regain their properties under their own power after damage. Developments to date promise good success with special, filled hollow glass fibers in composite materials.

Often these developments are accompanied and quantified with a life cycle analysis to evaluate the consumption of our natural resources as well as the impact on the environment.

Energy consumption in textile manufacturing

Textile finishing and coating is the most energy-intensive process in textile manufacturing. New technologies therefore need to be evaluated for their potential to save energy. These include the application of crosslinking solid systems without solvents and reactive hot melts, the use of minimal application technologies such as foam application processes, and innovative pretreatment methods based on ultrasound and plasma.

Complementing this, we are researching the further development of dryer systems with more efficient heat-substance transitions, with heat recirculation and heat recovery, and intelligent process control systems using AI methods. New methods of cross-linking finishes and coatings lead to energy savings in drying and achieve excellent properties. These include curing with electron beams and with ultraviolet light based on LEDs.

Good technological successes are being worked out with plasmas at atmospheric pressure and low pressure, which are increasingly finding their application in textile manufacturing.

AgroScale: Biodegradable ground cover nonwovens made from optimized natural fibers

In the AgroScale project, funded by the Baden-Württemberg Ministry of Food, Rural Areas and Consumer Protection, particularly sustainable agricultural textiles are being developed as a replacement for fossil-based systems such as films and synthetic nonwovens.

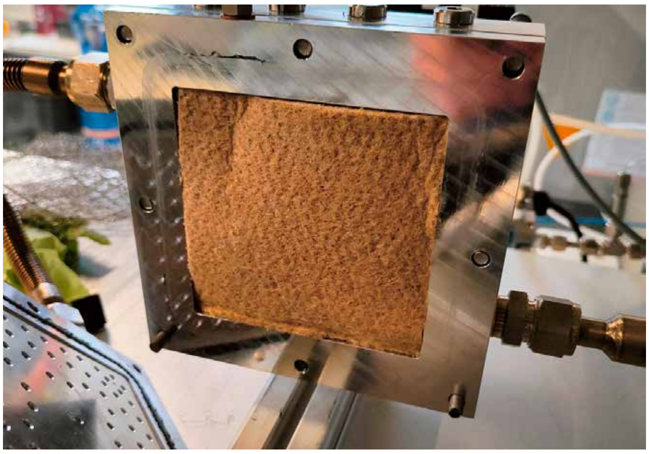
To prevent the growth of weeds and improve water retention, films made of polyethylene are currently predominantly used in the agricultural sector. Disposal of the low-cost films is often by thermal recycling due to contamination. Substitute textiles made of bio-based polymers and natural fibers are still too expensive for the intended use. In order to be able to reconcile low costs and sustainability, which are essential in the agricultural sector, large-area nonwovens made of low-cost, bio-based materials are being developed in the AgroScale project. The nonwovens made of natural fibers (silphia) in combination with lignin-containing fibers produced at the DITF are weatherproof and their durability can be adapted to environmental or weather conditions thanks to the adjustable lignin content.

Agricultural fleece after heat setting

After use, the materials can simply be plowed under and decompose without pollutants in the arable soil. This eliminates the need for costly disposal of films and nets, and no microplastics are released. The materials used are CO_2-neutral and can be used as a substitute for films and seed tapes. They enable better water retention, machine seeding and pesticide reduction.

CORA: CO_2 capture from air for power-to-X processes

According to the Intergovernmental Panel on Climate Change, in order to limit global warming to 1.5 degrees Celsius, around 1,000 gigatons of CO_2 must be removed from the atmosphere by the end of the 21st century. In addition to natural sinks – such as peatlands or forests – technical processes (direct air capture, DAC) are needed to reduce atmospheric CO_2 concentrations. CO_2 is a promising, almost inexhaustible and location-independent raw material that can be used, for example, in so-called power-to-X processes. DAC processes are therefore not only applicable for the storage of CO_2, but also stand as a key technology at the beginning of a non-fossil product chain. However, the extraction of carbon dioxide from the air is a complex process and currently requires large amounts of energy in the form of electricity and heat.



CO_2 adsorber installed in a measuring station

The focus of the collaborative research project "CORA" is the development of a cost- and energy-efficient CO_2 sorbent based on cellulose nonwovens and amines as a basis for competitive industrialization and scalability of the DAC technology. The idea is not to use a static filter, as is usually the case, which is baked out in batches after the amino groups have been fully loaded with CO_2. Instead, adsorption and desorption are to take place in a continuous process that permits permanent and energy-saving operation. The aim is to set up a demonstrator plant and, in parallel, to conduct a life cycle assessment (LCA) of the process at project partners. If the technology is connected to existing air streams such as building air conditioning systems or exhaust air, there is no need to use energy-intensive fans for air intake.

Optimization of the tearing and spinning process for sustainable fiber preparation

The production of torn fibers from used textiles and their processing into textile products has been an effective recycling solution for centuries and is thus one of the oldest material cycles in the world. In a joint IGF project, the DITF are working together with the STFI to produce a yarn with as reduced loss of properties as possible by optimizing and adapting the tearing process.

The path leads via the classification of the fibers, which includes the main feature of fiber length, as this is responsible for the strength in the yarn and is reduced by the tearing process. Pieces of yarn still contained in the recycled fiber mass have so far led to an incorrect measurement of the fiber length distribution. With the help of a newly developed test methodology, which was only made possible by the use of the MDTA-4 measuring device, this error could be eliminated.

This creates the basis for optimizing the tearing parameters on the machines and thus a higher quality of the torn products. As a result, the parameters and spinning components in the spinning mill can be adjusted and optimum yarn quality can be realized. The processing of recycled fibers according to the new methodology – in particular of 100 % aramid by means of compact spinning to ring yarns – improves the running properties and results in a higher strength compared to the open end yarn as well as a significantly higher resilience of the fabric produced from it.

In this way, yarns with a higher, as far as the aramid is concerned, even 100 % recycled content can be produced into economical and higher-quality recycled end products.

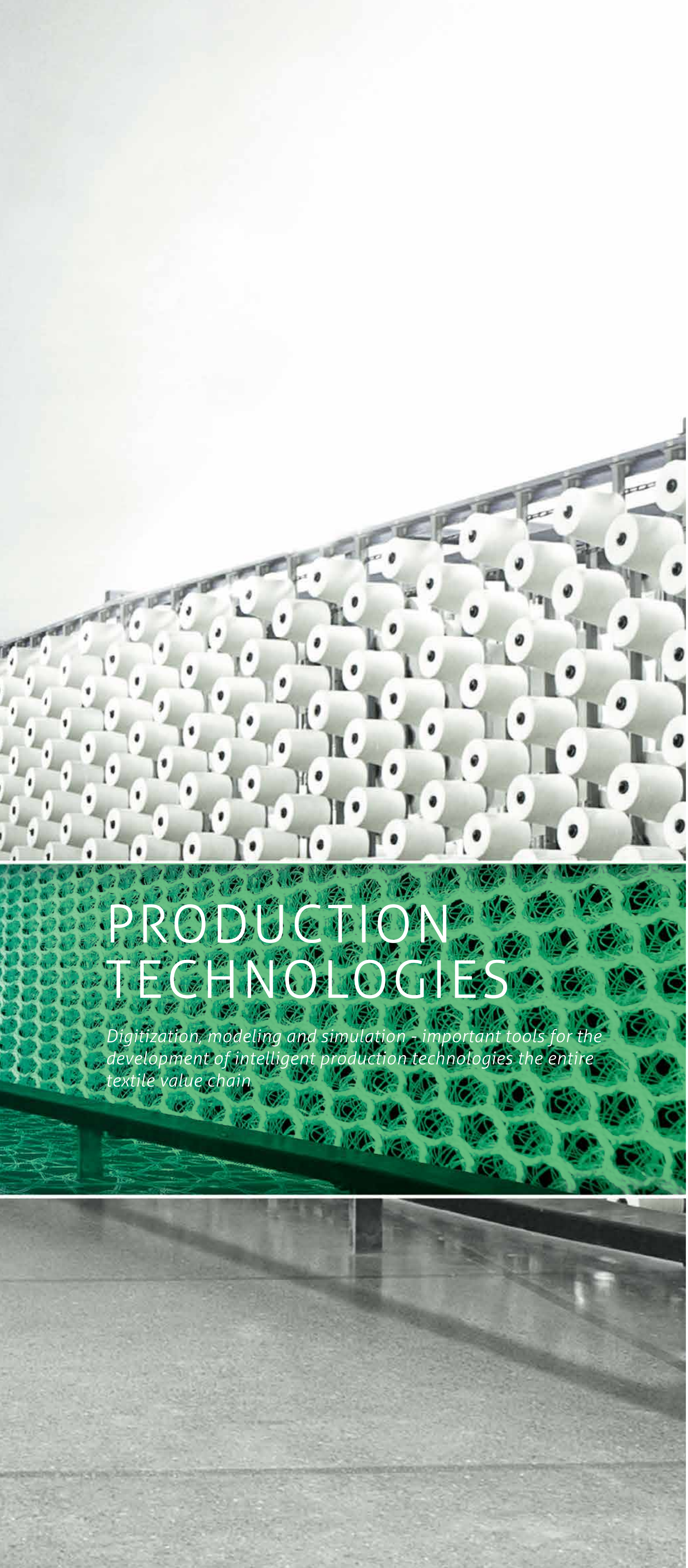
From recycled fibers to classification to yarn and knitted fabric

New plant fibers from crop residues – example lavender

In a joint research project, the DITF, the University of Hohenheim and the company naturamus are testing lavender varieties suitable for the region and developing energy-efficient methods to produce essential oil and fibers for classic textiles and fiber composites from it. The cultivation of lavender in the Alb means new territory. The University of Hohenheim is therefore testing five different varieties at four locations, which thrive differently depending on the weather and altitude. When the essential oils are extracted, a large amount of residual material accumulates that has not yet been utilized. Fibers can be obtained from the lavender stalk. Corresponding developments and analyses are underway at the DITF. In order to utilize lavender distillation residues, the plant stalks with their fiber bundles must be broken down, i.e. broken down into smaller fiber units. Within a fiber bundle, the lignified individual fibers are firmly connected by a plant sugar, pectin. This bond is to be dissolved, for example, with bacteria or with enzymes.

Lavender plants shortly before flowering on the trial field near Hülben

Various preparation techniques and methods are being investigated to produce long and short fibers from the material. Fine fibers are suitable for clothing, coarser fiber bundles for technical applications. The opportunities on the market are good. Regional value creation and ecologically and fairly produced textiles are in vogue. The focus is not primarily on clothing, but on technical textiles. The fiber composites that are also so important for lightweight construction can also be produced with renewable natural fibers.



PRODUCTION TECHNOLOGIES

Digitization, modeling and simulation - important tools for the development of intelligent production technologies the entire textile value chain

> Intelligent process control systems

> Digital technologies for the Industry 4.0

> Microfactories for the digitally networked production

> Textile functionalization with modern technologies

> Systems for human-machine interaction

> Modeling and simulation of processes as a basis for effective process optimization

> New processes for the manufacture printed sensors and actuators on textile

Production technologies

The DITF are the leading partner for industry in the fields of textile process engineering and textile and fiber chemistry. But we are also the preferred development partner for non-textile companies that see the advantages of fiber-based materials in new fields of application. Developments, considerations of sustainability, resource conservation, energy minimization and the recyclability of products are of crucial importance and are to be seen as guard rails within which our research work operates.

Technologies and processes for the circular economy

Under the conditions of the bioeconomy and the energy crisis, sustainable production technologies that protect the environment and conserve resources are increasingly being developed. Concepts and modes of action such as recycling or cradle to grave are being replaced by the demand for repeated recyclability of textile products. In addition, globally disrupted supply chains are forcing sourcing of (recycled) feedstock products to be as regional as possible.

This requires the development of reprocessing and recycling technologies as well as new materials. If we take a closer look, recycled polyester for clothing is currently often obtained not from textiles but from bottle flakes – in other words, from a different cycle. The material mixtures from which textiles are made are problematic. These cannot always be separated into their components. New process technologies must be developed that close the final step from end-of-life product to spinnable fiber in the circular economy chain. In addition, care must be taken to use fewer or single-variety materials in production.

There is also an urgent need for action in the textile value chain. Currently, only a small percentage of textiles are recycled because, for example, separating cotton and spandex is too costly. Future development challenges here are to develop new material properties with new production technologies, for example to give cotton spandex-like properties.

Carbon fibers have a high CO_2 footprint, raising questions about environmental compatibility. In order to continue to use the excellent properties on a broad scale, developments in the field of bio-based C-fiber and energy-reduced production as well as appropriate recycling technologies and processes must be developed.

Interdisciplinary networking as the key

The development of new process engineering and process technologies is effective when knowledge is available along the entire manufacturing chain – starting with the synthesis of fiber polymers, through spinning processes, textile surface production and functionalization, to the production of prototypes. Here, the DITF can draw on special know-how and the experience of employees with many years of experience. In a holistic approach, all aspects of the future product or technology are taken into account, i. e. technical, textile technological, economic and bioeconomic aspects. The basis for this is the intensive, interdisciplinary cooperation of experts from textile technology, mechanical engineering, process engineering, chemistry, physics, biology, cybernetics, computer science and economics.

Application-oriented research on 25,000 m²

For application-oriented research and development, industrial production technologies are available at the DITF on an area of 25,000 m², which are used, modified or further developed with regard to customer requirements. Production processes for the manufacture of fiber-based composites, 3D textile structures, digitally printed textile structures, high-performance fibers, etc. are available here under one roof. The machinery enables pilot and small series production close to industrial reality. Plant prototypes are developed, constructed and commissioned in a wide variety of projects.

In addition, the DITF support company and research partners in the field of electronics and control systems. Specialized technicians implement new ideas on testing and production processes for the textile industry in a modern, well-equipped mechanical workshop and in the electronics laboratory.

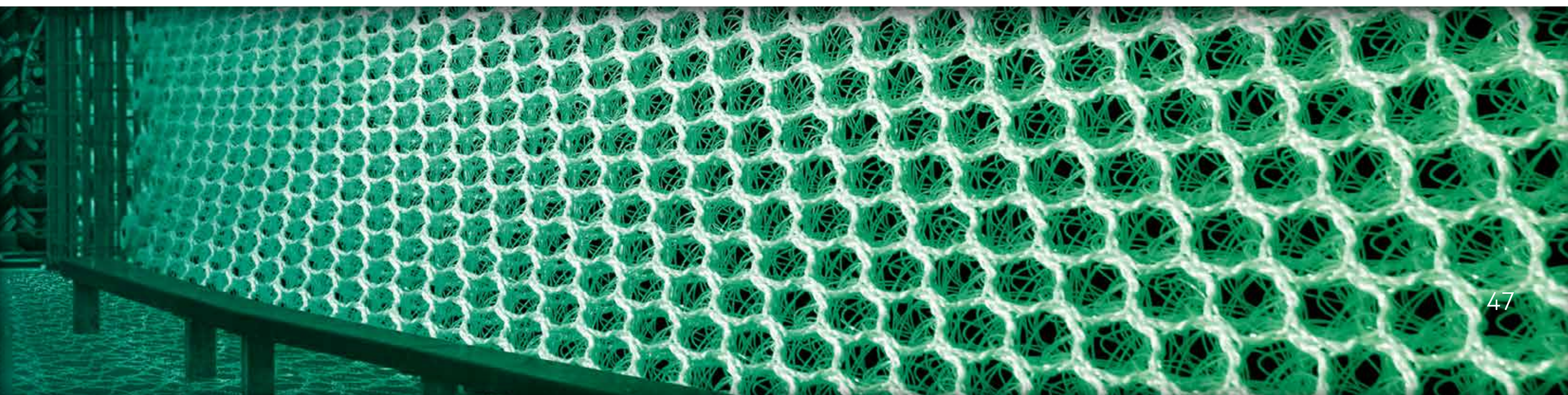
What does the future hold?

Supply chain problems also mean a real loss of value for the textile industry. Raw materials, primary products or spare parts are scarce and expensive. Flexibility is needed to produce smaller batches economically, to use raw materials for versatile applications and to find new sources of supply in Europe. Digital tools used in the area of data acquisition, data processing and traceability help here. As an example, a microfactory has been set up at the DITF in which complete production processes are implemented in this way.

Digitalization will also determine the future of textile process engineering and production technologies. Clear labeling and traceability are the basis for sustainable production and recycling management. The Digital Product Passport will become the central tool on the way to the circular economy, communicating, for example, the CO_2 footprint and other data from the LCA (Life Cycle Assessment) in the value chain up to the application and subsequent recycling.

In production, human-machine interaction/collaboration is increasingly being developed. By collecting and analyzing machine and product data, pattern recognition and creating appropriate models, machine learning and AI support process optimization and production analysis/optimization.

AI can predict machine and equipment downtime by continuously analyzing and predicting data from sensors and other sources. This allows AI to monitor processes in real time and automatically execute appropriate control actions.



Sustainability potential of microfactories

Sustainability is a key issue in the textile and apparel industry. Fast-moving trends, frequently changing collections, ecologically unfavorable materials and processes are drivers of negative environmental impacts. Microfactories around digital textile printing offer great potential for economic and ecological optimization of this process chain through digitally integrated product development and manufacturing in combination with modern information and communication technology.

Impressions of the demonstrator in the Microfactory Lab

In a current IGF project, the DITF investigated various scenarios with different technical issues regarding substrates (cotton, polyester), dye types (pigment, dispersion, reactive), fixation and achievable technical properties of the products in digital printing. Using material flow cost accounting (MFCA), process models were created and the multi-criteria analysis method was used to evaluate the different scenarios in terms of economic and environmental sustainability. For this purpose, an evaluation method was developed that can take different perspectives into account.

In addition, the concept of a flexible workflow solution was developed to improve the scalability of the microfactories, the spectrum of feasible products, the information technology coordination of processes, and the integration into production networks. This concept was implemented at the DITF in the Microfactory Lab as a demonstrator with the value creation stages from scanning to assembly. Companies can use this demonstrator to gain experience with microfactories and the flexible workflow solution in workshops.

Recyclable synthetic leather made of polybutylene succinate

Artificial leather usually consists of a PU- or PVC-coated, textile carrier (mostly PET). Chemical or thermoplastic-based recyclability is difficult or impossible due to the diversity of the polymer materials used. The aim must therefore be to build up the carrier as well as the coating from the same material, i.e. single-grade. Up to now, this has not been possible.

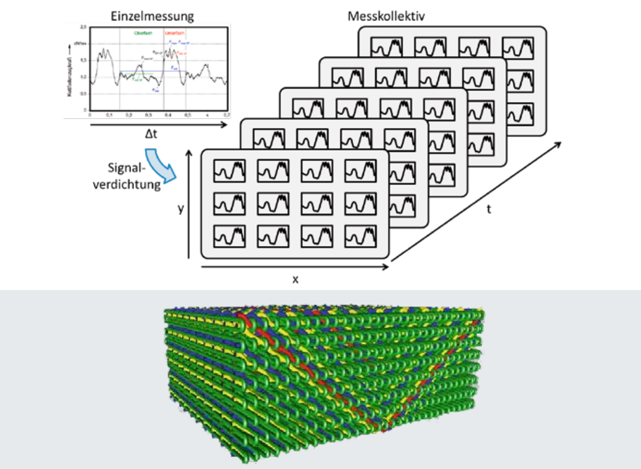
In order to realize a 1-component artificial leather, certain hurdles have to be overcome. On the one hand, the fiber material must be spinnable for the carrier and have sufficient mechanical strength. Secondly, the coating polymer must be highly flexible and resistant to environmental influences. In principle, the biopolymer polybutylene succinate (PBS) has a correspondingly suitable property profile. In an AiF cooperation project together with the Research Institute for Leather and Plastic Sheeting Freiberg (FILK), PBS filaments with good mechanical properties were produced at the DITF and further processed into sheet structures. These serve as substrates for subsequent coating, also with PBS.

PBS filament yarns produced at the DITF

A challenging task was to achieve the pore structures typical of artificial leather as well as good flexibility of the new PBS artificial leathers. For this purpose, special plasticizers are added to the hotmelts in the course of compounding. In addition to pore-forming agents, selected flame retardants are used as additives to reduce flammability.

Retrofit Multithread Sensor for Warp Tension Measurement on 3D-Weaving Machines

For future questions on quality and calculation of the performance characteristics of a component made of fiber-reinforced plastics, a continuously developed, digital information acquisition and monitoring of all relevant process steps is indispensable. A still unsolved information deficit is the measurement of all warp yarn tensions during weaving in a very confined space. Within the scope of a current project in cooperation with Hahn-Schickard Stuttgart, the basic principle of PCB-based sensor technology is used for the first time for the application case of multi-thread tension sensor technology. Several sensor concepts were simulated and tested, here capacitive sensor technology turned out to be the most suitable.



Detection of typical yarn tension curves and their assignment to the spatial bond structure

Measurements with prototypes showed promising results: typical patterns and temporal signal courses for different positions in the gate and for different yarns in the construction (e.g. pile yarns) could be identified and characterized. With this novel multi-thread sensor for parallel warp tension measurement of a large yarn array on 3D weaving machines, data for simulation and quality assurance of complex multilayer 3D-woven structures can be obtained in the future and evaluated using AI methods. The measuring principle of parallel recorded yarn tensile forces can be used as a retrofit concept for many other textile processes. Here, DITF and Hahn-Schickard combine sensor technology, process knowledge and AI methods into a very promising and innovative concept.

Technology component for a wear-reduced ring spinning drafting system

The drafting system has the greatest influence on the yarn quality and performance of a ring spinning machine. The state of the art is the double apron drafting system, which realizes the drafting of the roving to the desired yarn count. The fiber structure is guided in the main draft by means of endless elastomer aprons. Replacing the lower apron, e.g. in case of damage, is very cost-intensive, as the entire center shaft of the ring spinning machine has to be lifted and a correspondingly large number of personnel is required.

To replace the maintenance-intensive lower apron, the DITF have developed an attachable fiber guide element (FFE) in a current research project. Various materials, geometries and surfaces were investigated. Tests with the FFE in the processing of cotton, polyester and acrylic and long-term tests in spinning mills showed a consistent yarn quality and strength as in the processing with the double apron.

The use of the new FFE results in lower maintenance requirements and a correspondingly reduced need for personnel. Machine shutdowns for maintenance of the elements are no longer necessary when using the FFE. In the future, the elimination of the bottom apron could save the clamping device required for this.

The project was worked on jointly with the injection molding specialist HT Tooling, Bergisch Gladbach. Development at HT Tooling focused on the polymer and the injection molding process with the optimum coefficient of friction for the fibers and the suitable component surface.

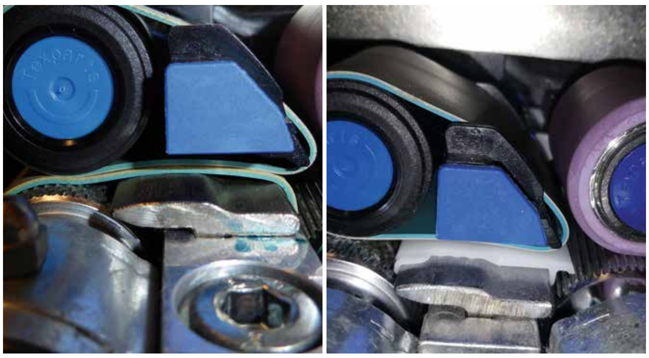


Illustration of the double apron drafting system with bottom apron (left) and with the FFE without bottom apron (right).

CLOTHING AND HOME TEXTILES

New and further development of textiles and processes. For more comfort, functionality, and sustainability.

- New fibers and technologies to improve mechanical, haptic, optical, or acoustic properties
- Antibacterial and antiviral finishes
- Development of fluorine-free and formaldehyde-free finishing processes
- Development of highly efficient halogen-free flame retardant finishes and coatings
- Finishing via physical processes (UV, ESH, plasma)
- Innovative carrier-free dyeing processes for high-performance fibers
- New dyeing systems for NIR camouflage
- Textiles with selective remission or reflection of thermal and IR radiation
- Compressive sports textiles
- Coated textiles, membranes, and laminates for comfort and security
- Textiles for art and light applications
- Sensor and actuator textiles through integration or printing on the respective circuitry, as well as fluorescent or electroluminescent colors and pigments
- Digital coloring and functionalization of textile procedures
- Textile lettering procedures for traceability and prevention of counterfeiting
- Virtual product development and retailer feedback processes within the clothing industry

Clothing and home textiles

Sustainability

The adoption of the "Green Deal" by the EU Commission in March 2022 and the eco-design regulation (Sustainable Products Initiative – SPI) it contains will have a serious impact on large parts of the textile industry. Manufacturers of fibers and textiles are being forced to rethink. Buzzwords such as "circular economy", "sustainability" or "life cycle assessment" are now part of the daily vocabulary in the textile industry. Existing products with poor recyclability, poor carbon footprint or potential for long-term accumulation in the environment will have to be replaced by sustainable alternatives in the future. Attention must be paid to this as early as the product design stage.

The special focus of research at the DITF is therefore – and has been for several years – on bio-based polymers for fiber materials and coatings. Current projects are dedicated on the one hand to the renewable raw materials cellulose and chitosan, with the focus on their derivatization with a view to their application in functional finishes and coatings. These include, for example, special cellulose derivatives for flame-retardant coatings that are suitable for textiles in the contract and automotive sectors. The modification of chitosan and alginate, for example, for hygiene applications is an interesting and current field of research.

Another readily available raw material is lignin. Current projects here are concerned with the investigation of different types of lignin and their suitability for coating yarns and textiles. Several polymer types with a biogenic raw material source, such as polyhydroxyalkanoate or polybutylene succinate, are also the subject of research projects, since they are now readily available on the market. With our competencies, we are part of national and European initiatives to establish broad-based networks with companies in the textile industry, with innovation laboratories, service providers and management consultancies.

Functional finishes and coatings

It is well known that the perfluorinated hydrocarbon compounds (PFAS) that used to be popular for waterproofing are to be completely banned. This affects not only the fluorinated C8 alkyls (PFOA), which were largely phased out several years ago, but also the C4 and C6 compounds developed as alternatives. All well-known manufacturers of textile finishing chemicals are therefore working feverishly on the development of fluorine-free alternatives. These are non-polar, strongly hydrophobic compounds such as compounds with a kerosene content, modified acrylates or dendrimers. To ensure that the effect is still sufficient after several industrial washes, it is customary to refresh the finish by means of a booster, depending on the stress cycle. The measures and requirements that apply to the alternative fluorine-free systems during refreshing are currently being intensively investigated and optimized. Exemptions from the PFAS ban are to apply to certain areas of workwear. Opinions currently differ as to whether PTFE coatings and polymer membranes made of ePTFE, which are important for many areas of application, will be allowed to continue to be used in the long term.

Since the development of new reactant crosslinkers, which are important for many permanent finishes, is hardly worthwhile for chemical manufacturers due to the REACH regulation, the trend in finishing is increasingly moving towards either docking active substances onto the fiber material via bio-based binder systems or directly applying active polymers in the form of coatings. The advantage is that proven and certified active substances can be incorporated into the polymers and used universally. This means that, on the one hand, the finishes can be applied relatively independently of the substrate to be finished and, on the other hand, they offer the possibility of combining desired functionalities with each other in one finishing or coating step. Interesting current projects at the DITF in this respect are, for example, the production of flame-retardant polymer coatings containing phosphorylated cellulose ("FRBiocoat") or the incorporation of antimicrobially active AgXX particles into polymer coatings, which exert their effect relatively independently of the type of textile substrate. The particles are a few micrometers in size and consist, as it were, of an "alloy" of silver and ruthenium. The effect does not result from silver release – which is an important criterion with regard to classification under the Biocides Directive – but is based, in the presence of moisture, on the formation of highly reactive hydroxyl radicals, which are capable of destroying bacteria and also viruses.

Spacer textiles may become interesting for certain applications in the future. Due to their special structure, these still exhibit elastic properties even after a functional coating, in contrast to relatively rigid fabric materials. One example from current research is the development of a new chemical protection suit.

Work on the continuous further development and adaptation of intrinsically effective fibers for clothing and home textiles is being carried out across centers at the DITF. A good example is the development of flame retardant carpets based on intrinsically flame retardant polyamide fibers.

End-to-end digital engineering and microfactories

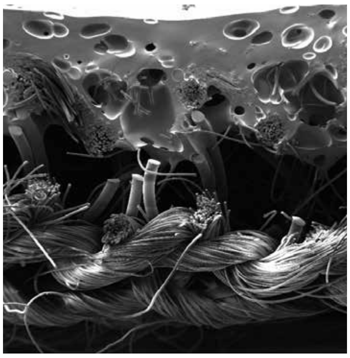
In order to achieve the targeted global warming of no more than 1.5 degrees, fundamental changes must take place, which can succeed through regional development and supply networks, among other things. This requires a fully interconnected, integrated chain for an on-demand network that uses digital technologies and allows individualized production based on demand.

With a Textile 4.0 multifunctional laboratory, the DITF are demonstrating the possibilities of digitalization and pointing the way for customized business solutions. End-to-end digital engineering from design to product is a milestone in the digital transformation, and not just from a technical perspective. Fully integrated, highly automated digital process chains also make entirely new business models interesting and lucrative. They save material costs and development times and allow a fast and highly flexible response to changes in the markets. As compact microfactories for regional or urban production of small batches or customized, individualized one-off items, they address current market trends. In the Mittelstand-Digital Zentrum Smarte Kreisläufe the DITF demonstrate a digital process chain for the apparel sector.

New design concept for chemical protection suits

Chemical protective suits (CSA) are used in fire department rescue operations, accidents involving chemicals, and maintenance work in the chemical industry. For today's CSA, the total duration of use is limited to 30 minutes. The reason for this is the high physical strain due to ergonomic restrictions. Including the compressed air supply, a CSA weighs about 25 kg. Due to their construction from a multi-coated fabric, they are heavy and stiff. Communication with the surrounding area and the control center is severely restricted.

„AgiCSA" – a newly developed chemical protective suit with significantly greater comfort



Flame retardant spacer fabric with an elastic barrier coating of butyl and/or fluororubber

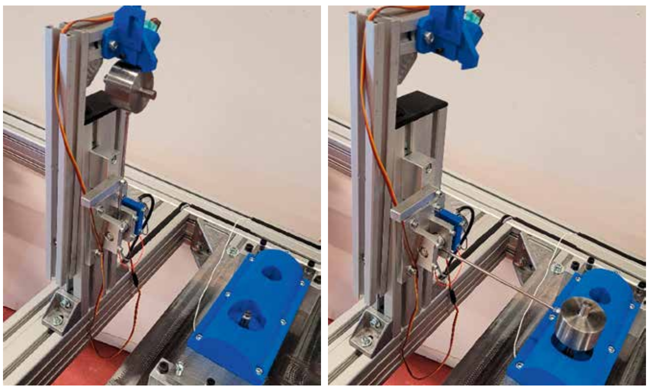
A joint project is currently working on completely redesigning both the textile material composite and the hard components and connecting elements between the two. The goal is a so-called "AgiCSA", which offers significantly more comfort for the emergency forces due to its lighter and more flexible construction. Textile composites made of flame-retardant spacer textiles are used, which are provided with an elastic barrier coating made of butyl rubber and/or a fluororubber. For the hard components, i.e. the helmet as well as the back carrier for the compressed air supply, lightweight carbon fiber reinforced composite materials are used.

The new design is modeled on modern dry suits with diagonal, gas-tight zippers. This makes it much easier to put on and take off the suit. In addition, the new AgiCSA has integrated sensors that allow the transmission and monitoring of vital and environmental data of the emergency responder as well as their location via GPS data. The new suit concept makes it possible to significantly extend the time the suit can be worn in the field.

Soccer sock with integrated protection for shin, calf, ankle and Achilles tendon

Accidents in soccer rank first among sports accidents in Germany. Depending on the source, their share varies between 22 % and 44 %. Injuries to the lower leg account for 10.8 % and to the ankle for 13.6 %. Current shin guards are limited to protecting the tibia and take the form of a hard front shield or a soft construction. In some cases, they have only rudimentary ankle protection.

In a ZIM project, the DITF are developing a soccer sock that is intended to prevent or significantly mitigate 80 % of previous injuries in the lower leg area. For this purpose, new mechanical principles for the effective dissipation of force impulses are being implemented. Central functional elements are force-impulse-dissipating textile base frames with additional integrated mechanical absorber structures for the shin and calf, as well as protectors to protect the ankle and Achilles tendon. Effective force impulse dissipation cannot be implemented by individual, punctual and one-dimensional absorption mechanisms. Therefore, an integral overall sock construction is required, which is part of the force management and at the same time ensures that during running and normal ball contact, the specific functional elements do not shift or twist and thus cannot fulfill the protection of the lower leg at the decisive moment.



Developed test rig for checking pulse distribution and dissipation in absorber structures

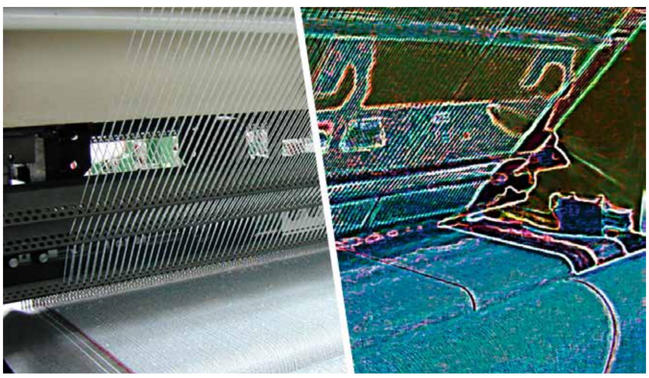
At the same time, the soccer socks must have a high geometric form fit. To achieve this, they are redesigned in terms of their spatial structure in terms of knitting technology and the protection of the ankle and Achilles tendon is integrated in addition to the shin and calf.

Resource-efficient development of tufted floor coverings through digital twins and AI

The development of textile products is associated with high material, time, personnel and cost requirements. The corresponding development processes are characterized by an empirical approach based on the know-how of experienced specialists. This knowledge is often hardly documented and thus cannot be retrieved and reproduced at will at any time. Due to the age structure of employees in the textile industry and the general shortage of skilled workers, the long-term transfer of knowledge is thus at risk. This applies in particular to the development and manufacture of textile floor coverings, which are characterized by long product life cycles. The challenges here are therefore, in addition to the efficient development of new designs, ensuring consistent product quality. This is especially true for established products, provided that the raw materials/semi-finished products that can be supplied vary and may consist of recycled materials.

AI-assisted development process

In an IGF project, the DITF together with the TFI at RWTH Aachen University are developing Digital Material and Process Twins that can be experimented with and used in conjunction with AI methods to realize digital product development. This digital development process, supported by AI, enables accelerated adaptation to varying properties of precursors and varying product designs, as well as rapid stabilization of processes, especially when using recycled materials. This in turn reduces scrap and the use of resources, thus increasing process efficiency – even for small batch sizes. Overall, a reduction in development costs of up to 60 % is expected.

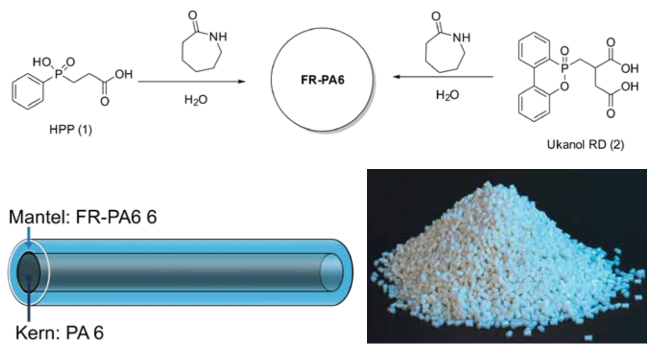


Tufting machine and its digital twin – symbol image

Development of a circular economy-capable textile floor covering

In the AIF project InFlameTex, intrinsically flame retardant polyamide 6 (FR-PA6) bicomponent fibers are being developed on the basis of DITF patents and processed into carpet at the Teppichfaser- Institut Aachen (TFI).

The FR-PA6, synthesized at the DITF using organophosphorus compounds from Schill & Seilacher, is extremely resistant to washing, unlike flame retardants that act as additives or coatings, because the flame retardant component is polymerized into the polymer chain. The FR-PA6 is melt spun into core-sheath bicomponent fibers, where the core is conventional PA6 and the flame retardant FR-PA6 is incorporated into the fiber sheath. In this way, the more expensive flame retardant component is used selectively and in a material-saving manner where the flame retardant is primarily effective. The conventional PA6 improves the mechanical stability of the fiber in the core and reduces costs.



Top: Schematic of polymer synthesis; bottom left: Structure of the core-sheath bicomponent fibers; bottom right: Flame-retardant PA6 pellets synthesized at DITF

During spinning of the FR-PA6 bicomponent yarn, winding speeds of 4,000 m/min were achieved, which are typical for polyamide 6. The yarn was processed into a knitted fabric and exhibited an LOI of 37.3 in the DIN EN ISO 4589-2 fire test. This yarn will now be produced in a 50 kg batch and processed into textile floor coverings for the contract sector at the Teppichfaser-Institut Aachen (TFI). Finally, the flame retardancy will be tested in LOI and UL94 fire tests.

In addition, the DITF are carrying out basic tests on the thermo-mechanical recycling of the bicomponent yarns. This means that the bicomponent yarns are re-extruded and incorporated into the sheath and/or the core.

DITF BODIES

The DITF – founded in 1921 – are a non-profit research institution in the legal form of a foundation under public law. They fall under the jurisdiction of the Baden-Württemberg Ministry of Economic Affairs, Labor and Tourism.

The supervisory body of the DITF is the Board of Trustees. It advises the Management Board on questions of professional and structural orientation and includes representatives from science and business administration and representatives from the ministries of Economic Affairs, Labor and Tourism as well as Science, Research and Art of the state of Baden-Württemberg. The scientific advisory committees of the research institutes provide topic-specific advice directly to the specific fields.

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