DEUTSCHE INSTITUTE FÜR
TEXTIL+FASERFORSCHUNG

ANNUAL REPORT 2020

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

DITF

DEUTSCHE INSTITUTE FÜR
TEXTIL+FASERFORSCHUNG

ANNUAL REPORT 2020

FOREWORD

Dear Reader,

The year 2020, as for all other institutions, was also marked for the DITF by the major challenges brought about by the COVID-19 pandemic. The DITF faced the major changes with commitment, creativity and openness. The necessary adaptation of work processes and communication formats was implemented almost overnight at the beginning of the pandemic and created the conditions for continued successful, stable and, despite Covid, lively research work.

Covid research

With numerous research projects and support activities, the DITF were able to contribute to the management of the Covid pandemic. At the beginning, when there was a shortage of protective masks everywhere, the DITF reacted immediately and converted their research pilot plant for the production of nonwovens for certified FFP2 protective masks. In parallel, the Denkendorf scientists advised companies and organizations in this exceptional situation. Where can I find suitable filter media for textile masks? What normative requirements must they meet? Who can carry out the certification? With their textile expertise and knowledge of the procurement infrastructure, the DITF were a valuable know-how supplier here for many companies, especially in the SME sector.

The first emergency measures were followed by many other projects to cope with the Covid pandemic. The focus was on pragmatic solutions for the production and optimization of protective clothing and masks as well as approaches to avoid supply bottlenecks. Among other things, the DITF launched a project to develop reusable medical face masks based on high-precision air-jet weaving technology. The impetus for this was provided by the weaving machine manufacturer Lindauer DORNIER, and the realization was supported by the Baden-Württemberg Ministry of Economics.

DITF Strategy Process 2021

In connection with the DITF Strategy Process 2021, decisive restructuring measures were completed last year. The new structure with 6 competence centers, 4 technology centers and one service center follows a stringent thematic focus of the comprehensive research activities at the DITF (see report page 12/13).

The DITF stand for excellence in applied research and in the transfer of findings from basic research into practice. The most important task is and remains the development of marketable products, processes and services for industry and thus the orientation of our work to the needs of industry. With the reorganization and the associated structuring of our differentiated competencies, we will be able to fulfill this task even better in the future.

Focus topics digitization and sustainability

For many years, our research was primarily determined by technical innovations for higher productivity, greater effectiveness and flexibility. The digital transformation process and the enormous challenges posed by climate change have reset the thematic priorities – digitization and sustainability are now the focus.

The "European Green Deal" addresses a broad spectrum of research topics. There is a large number of tasks that need to be solved on the way to climate neutrality and sustainability in Europe. Textile products and processes that we develop at the DITF offer a variety of forward-looking solutions. The Annual Report 2020 presents current research projects on the classic sustainability topics of energy and resource efficiency, recycling and renewable raw materials with different application focuses.

At the same time, digital technologies of the future now play a central role in our research projects – be it to optimize development and production processes through "digital engineering" and to develop solutions for digital transformation, or to advance the functionalization of textile products by integrating electronic components. On the way to Industry 4.0, the DITF are making an important contribution with, among other things, the Digital Textile Micro Factory and the 4.0-Kompetenzzentrum *Textil vernetzt.*

The basis for the continuation of our successful research in the Covid pandemic are our employees. Even under the changed working conditions, they have remained highly motivated, reliable and committed to textile research with an impressive willingness to perform. We would like to express our heartfelt thanks for this contribution in an extraordinary year!

We hope that the pandemic will soon come to an end and that we will once again be able to meet our customers and partners without restrictions. Despite all the routine in the new communication formats, we still miss the personal contacts and the direct exchange with you. We therefore look forward to seeing you again and would like to thank you for the trust you have placed in us during the crisis.

Sincerely

Your DITF board of directors

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

Prof. Dr.-Ing.
Götz T. Gresser

Peter Steiger

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> Publicly funded research projects

> Published final reports, publications, lectures, press releases

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> Events, trade shows, exhibitions

> Patents

> Bodies, scientific advisory councils

Orders: info@ditf.de

DITF

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.

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.

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.

Technology and knowledge transfer in practice

The DITF quickly transfer sustainable research results into economic exploitation 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

Institute for Diversity Studies in the Engineering Sciences
Prof. Meike Tilebein

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!

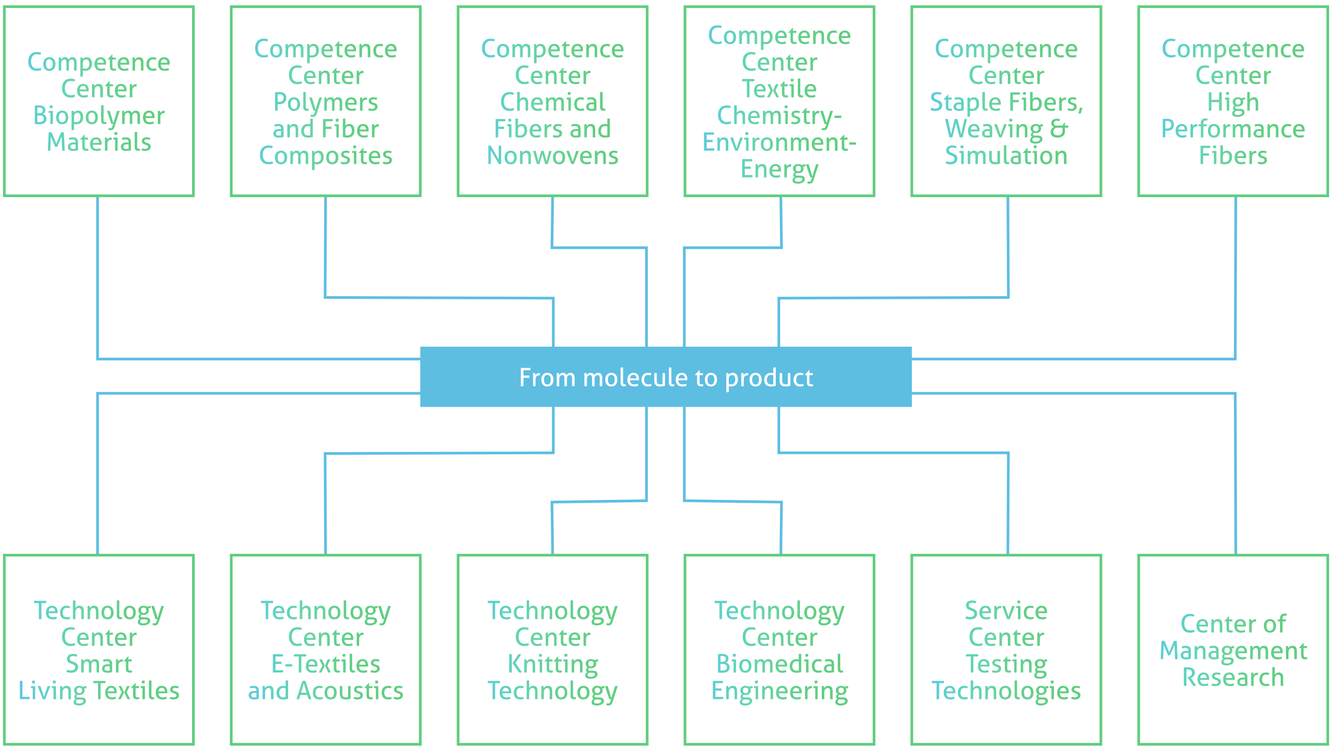
DITF REORGANIZATION

Combining forces. Strengthen strengths. Exploit synergies. With a structural and strategic reorganization, the DITF are making even better use of their services and their innovative strength.

Prof. Dr.-Ing. Götz T. Gresser,
Chairman of the Board

2020 was marked by the structural and strategic restructuring of the research and development areas at the DITF in order to align research even more efficiently across the entire textile value chain. The new structure with 6 competence centers, 4 technology centers, the Center of Management Research and a service center follows a stringent thematic focus of the comprehensive research activities at the DITF. It sharpens the profile of the DITF and bundles already existing competences. This allows the strengths and, above all, the overarching unique selling proposition of the DITF to stand out more clearly. All areas offer the opportunity to research and develop along the entire textile chain.

The competence and technology centers form the basis for the strategic targeting of research topics, the expansion of research priorities and the infrastructure required for this, and the use of synergies in internal cooperation.



Competence Center Biopolymer Materials

Development and production of technical fibers and materials based on biopolymers such as cellulose, chitin, keratin, alginate or lignin by using new highly effective solvents, e.g. from the class of ionic liquids (ILs).

Competence Center Polymers and Fiber Composites

Production and further development of polymers for fibers, textiles and matrix systems as well as the optimization of textile processes and fiber composite technologies – from polymer synthesis to the component with a close integration of polymer and process engineering.

Competence Center Chemical Fibers and Nonwovens

Development of man-made fibers and nonwovens for technical applications as well as technologies for their production – from melt spinning of fibers to the production of nonwovens in direct nonwoven processes and carding technologies.

Competence Center Textile Chemistry-Environment-Energy

Functionalization of yarns and textile surfaces, including through finishing, modification, printing, coating or laminating. The aim is to improve textile materials and processes in terms of functionality, energy efficiency and ecology.

Competence Center Staple Fibers, Weaving & Simulation

Research and development along the value chain from the fiber flock to the yarn or twisted yarn to the woven surface, supported by simulation of production processes and products. The competence center provides technology transfer from feasibility to small-scale production from a single source.

Competence Center High Performance Fibers

Research and development, production and analytics of high-tech fibers based on resource-saving and sustainable new technologies for applications with extreme requirements in terms of strength, stiffness, weight reduction or temperature resistance. The focus is on the development and production of carbon and ceramic fibers.

Technology Center Smart Living Textiles

Research and development of hybrid products with integrated functions such as light and sound textiles, climate-regulating textiles for the smart home, smart city or living walls. Integration of functions through sensors and/or actuators in textiles.

Technology Center E-Textiles and Acoustics

Development, assembly and production of textile electrical sensors and actuators as well as smart sensory PPE incl. AVT and measurement and control technology, data processing. In the field of acoustics, development of textile sound absorbers and metamaterials.

Technology Center Knitting Technology

Development of circular and flat knitted fabrics for various clothing-specific and technical applications as well as measurement and process engineering developments on knitting machines for the technical optimization of machine elements and machine functions through to tasks within the framework of Industry 4.0.

Technology Center Biomedical Engineering

Development and production of textile-based products for medical technology – from raw material through all innovation steps to the finished product. The focus is on fiber-based absorbable implants (incl. clean room production, certification), drug delivery systems, antibacterial and antiviral systems (evaluation), nerve regeneration and textile-based monitoring of physiological parameters.

Service Center Testing Technologies

Textile testing and analysis of fiber-based materials in accredited laboratories (DIN EN ISO/IEC 17025) with a comprehensive service catalog of textile-technical, chemical, biological and sensory test methods for testing fibers, yarns, surfaces and textiles.

Center of Management Research

Intelligent, self-organizing functional units and technologies for Industry 4.0. End-to-end digital engineering (modeling, virtualization) in the development and production of textiles as well as analysis and design of sustainable value creation systems. Predictive maintenance and quality.

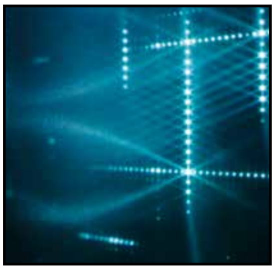
DITF RESEARCH FIELDS

The six strategic research fields of the DITF use the unique feature of textile vertical integration for knowledge-based innovations. As the only textile research institution in the world the DITF cover the entire production and value creation chain of textiles.

From the molecule to the finished product

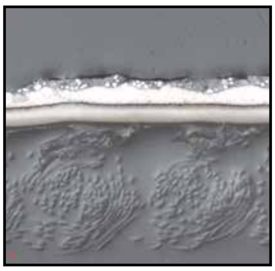
High-performance fibers and yarns

Development of high-performance fibers and yarns on the basis of synthetic polymers and sustainable raw materials



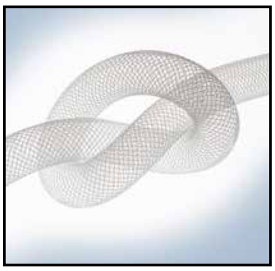
Smart textiles

Integration of existing technologies for the development of more active, more adaptable, more sensory and shinier textiles



Textile finishing and coating

Development of functional technical textiles with new environmentally friendly technologies

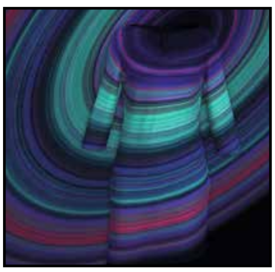


Medical technology

Biologization of medical textiles and implants with active substance delivery systems and more active surfaces

Composite fiber and lightweight construction

Development of end-contour 3D-components with composite fiber technology



Textile 4.0

Digitization, process development, value creation and knowledge management in the textile and clothing industry

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 nursing

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

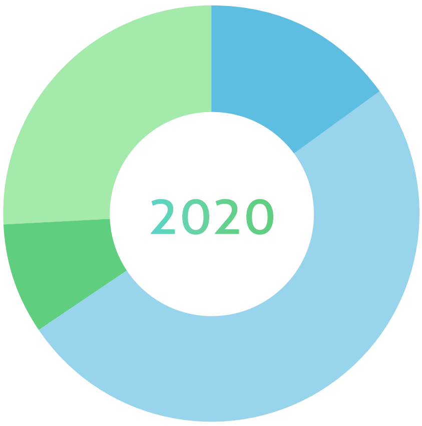
Fibers, structures and products e.g. for the automotive industry and for aviation and space travel technology

Clothing and home textiles

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

FIGURES – DATA – FACTS

23.882 Total revenue



- Revenues Industry: 5.203 TEUR
- Revenue from public contracts: 10.698 TEUR
- Other revenues: 2.456 TEUR
- Institutional funding: 5.525 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 2020 was approx. 60 %.

139 Public research projects

Subsidies from state, federal and EU programs. 31.0 % 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.

53 publications were published

37 of these have appeared in peer-reviewed journals.

12 bachelor's theses,

15 master's theses and

7 dissertations were completed and published.

10 patents were published

Employees as of 31.12.2020

DITF

233	employees
	106 scientists* and engineers*
	127 non-scientific employees
11	doctoral students
39	students (Bachelor and Master students)
42 %	share of women in science and technology

ITV Denkendorf Produktservice GmbH

46	employees

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 Biomedical Technology Development Division, the PET yarn and PGA nonwoven production division and the ITV Denkendorf Produktservice GmbH are certified according to EN ISO 13485:2016. Scope: Development, production and distribution of absorbable and non-absorbable polymers, films and membranes, surgical sutures, implants, wound dressings and antimicrobial 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, 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 12 non-academic, business-related research institutes 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 4,700 industry projects per year, the innBW is an important partner, particularly for SMEs.

ZUSE-GEMEINSCHAFT

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.

ARCHITECTURE AND CONSTRUCTION

Fiber-based materials and processes for their processing in the construction industry. Improved aesthetics, greater sustainability, functionality and innovation. For temporary and permanent buildings.

> Textile facade elements: intelligent, light building shading

> Light-guiding textiles

> Smart textile construction elements

> Pneumatic textile actuators

> Autonomous living walls

> Textile moss walls for particle reduction

> Optically transparent fiber reinforced materials

> Textile solutions for Smart Home & Smart Quarter

> AI in construction

> Sonic textiles

> New membrane materials for textile construction

Architecture and construction

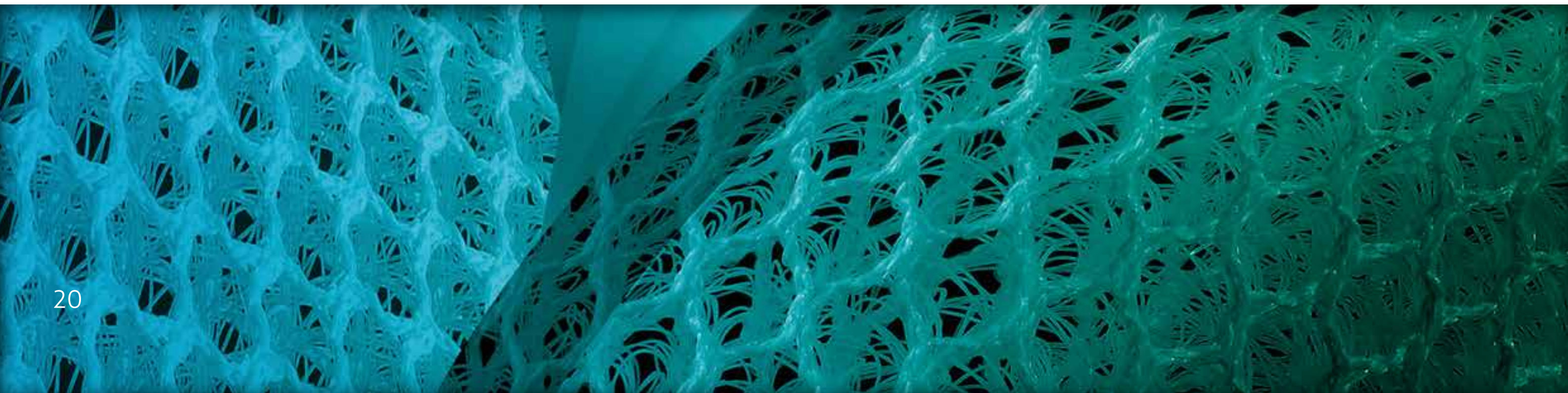
Urban redensification, smart quarters, attractive solutions for living in the countryside – these are all future tasks that require innovative approaches. Improving air quality in metropolitan areas and optimizing the use of resources are also challenges for which the DITF are developing solutions for the construction industry. The changes resulting from the COVID-19 pandemic in the use of buildings also represent a new challenge. Ever-shrinking homes in metropolitan areas require additional demand for innovative solutions in the context of home offices and homeschooling

Functional, smart building textiles

To address these future challenges, the DITF are developing new textile solutions using new materials, structures and control systems to create new parts, components and products for the entire field of construction. The focus here is on integrated solutions. Accordingly, they protect from exposure to climatic influences as well as sound and light. Materials and components must fulfill structural, energetic, and design functions. Fiber-based materials prove their worth especially in the context of such multiple demands. In combination with AI solutions this potential opens up for the user. The DITF develop feasible, efficient solutions for this purpose to enable qualitative and social densification.

Textile solutions for redensification

The Denkendorf ResearchCUBE allows us to develop ideas; moreover, test and demonstrate new approaches, which then results in the rapid introduction of new products. New shading textiles achieve optimum light distribution in the interior of a building because even though they reduce glare, they direct so much valuable daylight into a room that artificial lighting becomes unnecessary. Integrated textile sensors both measure the illuminance and control AI-supported textile-based actuators that adjust the shading depending on the position of the sun. Within the framework of the Mittelstand 4.0-Kompetenzzentrum *Textil vernetzt*, companies are supported in implementing such AI-based applications. In an AI Escape Room set up for this purpose, the possibilities can be experienced in a playful way. These textile AI solutions cannot only be used in the smart home, but also open up further possibilities in the area of smart districts. Here, tasks are no longer addressed in the individual object, but are solved in the intelligent networking of several buildings. Research is focusing here on issues related to energy production and consumption as well as water supply and wastewater disposal in increasingly sealed areas.



Building facades also hold excellent potential for solving problems of redensification. Textile facade systems can be produced to be lightweight, flexible, and highly functional. Attached vertical greenery systems (living walls) not only improve the quality of the air and life in densely populated city centers, but their water retention capacity also makes them suitable for urban water management. Even textile roof constructions in the form of membrane structures have long become a part of permanent buildings. Accordingly, thanks to their low weight and flexibility, textile materials allow the roofs of stadiums, train stations, and airports to be versatile like no other material.

Fiber-reinforced composites in construction

Fiber-reinforced composites have industrially relevant properties as a result of their great specific strength and rigidity; subsequently, they are becoming increasingly important for use in construction. Moreover, the orientation of the fibers, adhesion at the fibermatrix interface, as well as the many possible combinations of fibers and polymeric matrices, make it possible to adapt the material properties to various applications. The emerging digital transformation of everyday life and industry increasingly demands complex materials that, in addition to their usual intrinsic characteristics, have additional features such as artificial "sensory organs" to remain competitive in an ever more interconnected environment.

Adaptive covers and structures for the built environment of tomorrow

Within the framework of the Collaborative Research Center (SFB) 1244, fully transparent fiber composites were successfully developed as load-bearing components for buildings and shells with integrated sensors for monitoring deformation. These fully transparent fiber matrix systems are now being further developed together with the Institute of Aircraft Design at the University of Stuttgart and industrial partners.

Nature as a model for textile structures for horticulture

The challenges of growing plants in greenhouses include managing humidity, water supply, and water treatment. There are also efforts to use planting substrate alternatives to peat for ecological reasons. In addition to the currently available substrate alternatives such as rock wool and perlite, other biodegradable substrates are in demand.

The AiF research project "Textile Moisture Transfer" demonstrated how textile structures can be systematically developed to meet these challenges using models from living nature. For this purpose, process models of biomimetics were integrated into systems engineering. In this way, role models from nature can be systematically investigated and converted into technical parameters for textile production.

Planting trials with moisture distribution and storage fleeces

The procedure was tested in three horticultural scenarios in the greenhouse. The water hyacinth and various deciduous and sphagnum mosses, which have interesting properties with regard to water storage, transport and evaporation, served as models. In these application scenarios, new textile evaporator structures as well as textile moisture separation, moisture distribution and storage fleeces were developed with the help of biomimetics. Thus, mineral-free moisture supply, combined heating support and water sterilization as well as alternative plant substrates can be realized for greenhouse horticulture.

The research project has thus shown that, with the help of living nature and a systematic approach, textile solutions can be made possible for very different non-textile applications such as horticulture.

Intelligent textile surfaces for smart home applications

Smart textiles are playing an increasingly important role today, but especially in the future. In the BMBF-funded project "Textile Surfaces for Power Supply, Communication and Intuitive Interaction in the Smart Home", or CONTEXT for short, companies and research institutes have joined forces to develop a novel wallpaper with interactive elements for smart home control. Project partners along the value chain are the German Research Center for Artificial Intelligence GmbH, Robert Bosch GmbH, the German Institutes for Textile and Fiber Research Denkendorf (DITF), the Fraunhofer Institute for Manufacturing Technology and Applied Materials Research, Norafin Industries GmbH, and Peppermint Holding GmbH.

The interactive textiles can be integrated into standard smart home protocols. They enable various haptic interaction patterns such as touching, swiping, or stretching to configure applications and scenarios. In addition, lighting and display elements are integrated into the textiles to indicate the current status of the smart home network as needed. The smart wallpaper thus forms the basis for intelligent assistance. The DITF are responsible for sensor development and the textile construction of the interactive wallpaper. Legal aspects such as data protection, social issues and environmental and sustainability considerations are discussed using a test family consisting of parents, children, and grandparents.

Smart interactive wallpaper

3-D textiles for lightweight, load-bearing building envelopes

Innovative applications in the wall and roof area of the construction industry are created by a material-pure composite in a new textile structure. A basalt spacer fabric is used as a lost formwork element to give shape to the building element and to transfer tensile and shear forces in the composite. Filled with lightweight foamed concrete and a top layer of UHPC concrete, the result is a lightweight and highly efficient composite material that provides good building insulation and high stability at the same time. In terms of sustainability, the textile-based building envelope scores points for its complete recyclability thanks to the same basic materials used for the fibers and infill.

Basalt spacer fabric with pile thread spacing 150 mm

In a project involving architects and civil engineers, interdisciplinary solutions are being developed based on the use of basalt spacer fabrics as a lost formwork element. The spacer threads inserted between the two fabric layers allow the fabric layers and thus the geometry of the component to be defined in terms of shape, the load-bearing capacity to be adjusted and the material cohesion to the foamed concrete to be ensured. A thin layer of UHPC concrete, in interaction with the basalt-foam sandwich, completes the structural properties of the building composite.

The conceivable areas of application for the new material composites are facade or ceiling elements with reduced transport and formwork requirements and a significantly increased insulating effect in a structure-optimized construction method.

ETFE cushions for conventional modular facade systems

Transparent facades have so far been dominated by glazing. Building envelopes made of flexible membranes offer attractive alternative design options. ETFE membrane cushions have so far found their way into specialized membrane building architectures, especially in the roof area. For integration into conventional modular facade systems, the interface to the membrane, an installation concept and an industrial manufacturing process for standard modules have been lacking until now. At the DITF, joining processes have been developed for industrially mounting ETFE films on slim, thermally insulated profile frames.

Welding ETFE membranes to aluminum

In order to thermally join ETFE membranes to aluminum profiles, the aluminum profiles were powder-coated with ETFE in advance. The ETFE membranes were then thermally welded to the coating by means of heat contact. The joining process and frame construction method enable industrial prefabrication of interchangeable modules in membrane design.

ETFE facade elements in the outdoor weathering facility at DITF

HEALTH AND CARE

Textile materials, products, and processes concerning innovative applications for the medical care of people.

- > Resorbable polymers and biomaterials
- > Implants
- > Cell scaffolds for regenerative medicine, biohybrid artificial organs
- > Closure device for blood vessels and nerve guidance conduits made from biopolymers
- > Drug delivery systems: capsules containing therapeutic agents and porous fibers
- > Ceramic fibers for bone replacement
- > Bioactive coatings, for example as wound dressings
- > Sensory textiles for telemedicine
- > Personalized orthoses
- > Physiologically optimized stockings
- > Wound dressing materials
- > Hospital and surgical textiles
- > Antibacterial textiles

Health and care

The importance of research and development in medicine has probably come to everyone's attention in the last 12 months since a small virus changed all our lives. On the one hand, we seem to be helpless against the spread of the virus, but on the other hand, research has made such great progress, especially in vaccines, that there is justified hope of getting COVID-19 under control.

In addition to direct control of the virus, indirect measures also play a major role. The DITF have participated in mask production and are currently involved in a number of projects to limit the spread of viruses and bacteria on surfaces or through masks/filters and thus render the pathogens harmless before they even reach our mucosa. This has not only been an issue since Covid, but has long been of interest due to increasing so-called nosocomial infections in hospitals. Here, the DITF not only have many years of experience in the functionalization of fibers and coating of textiles, but also a wide range of options in the test laboratory for evaluating the effectiveness of such finishes.

Digitization for fitness

Digitization is permeating more and more areas of our lives – the pandemic has given this development another significant boost. Currently, many people have switched to the home office and many find it appealing, so this form of work will continue to be used frequently even after the pandemic. Here, as in the traditional office, however, our health suffers from a lack of exercise. The sensor mat developed by the DITF together with partners in the Go, WannaGo project is designed to help make exercise breaks not only fit, but also fun.

Individualized therapies

We humans are very different from birth. That makes life exciting, but it's a problem for any therapy because every form of treatment tends to be tailored to a general case rather than the specifics of an individual patient, if only for cost reasons. Here, too, digitization helps us a great deal because it makes it possible to cost-effectively tailor therapies to an individual's very unique form of illness, as was demonstrated in our project on scar treatment with compression textiles.

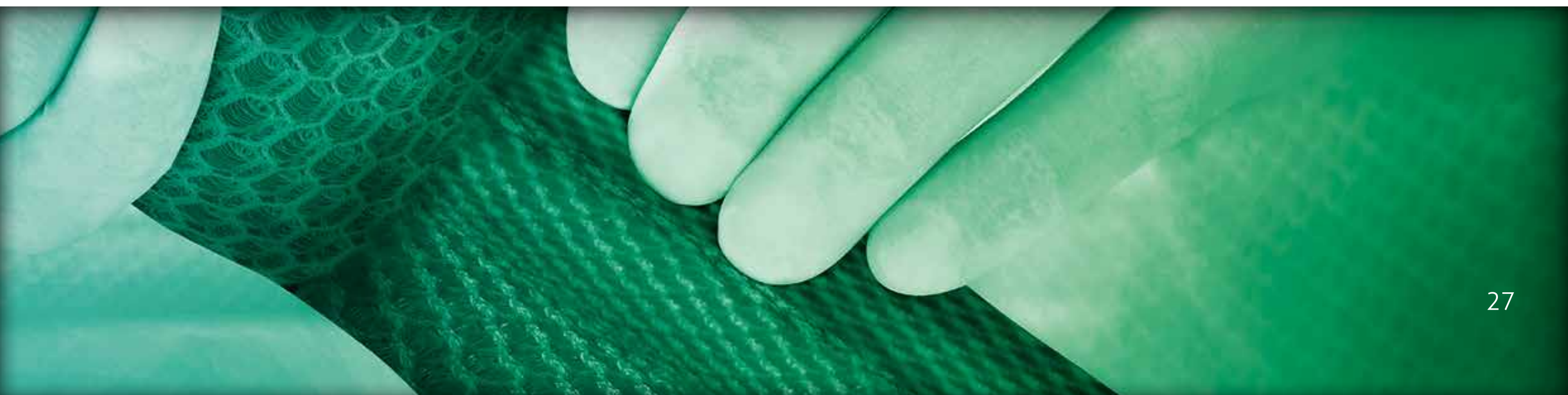
Digitization in clothing

Another very individual phenomenon is the physiological problem of feeling cold and losing heat through clothing. In skiing in particular, there have long been various approaches to preventing chilling by means of electric heaters in clothing or boots. However, it only becomes interesting when a control loop is formed by appropriate sensor technology that prevents excessive heat dissipation or, if necessary, even cools. This is not only a question of comfort, but would also be helpful, for example, during patient transport or surgery. In a large European joint project, the DITF have carried out fundamental research in this area.

Organs from the printer

Regenerative medicine is also making great progress. Fiber-based materials have now established themselves as carriers for cells (especially nonwovens) and as guide structures for controlling regenerative processes in the body. At the same time, advances in 3D printing have also opened up new possibilities for manufacturing individualized implants. New is the approach pursued at the DITF now to manufacture and combine electrospun nonwovens and 3D-printed elements in a single additive manufacturing process in a printer. This opens up new, interesting possibilities for implants for regeneration in the body, in which stiff and soft structures are also combined.

The DITF are excellently positioned in medical technology. For more than 40 years, fiber-based medical products have been researched and developed here in an interdisciplinary manner, from polymers to implants or hospital textiles. They offer the entire spectrum of innovative medical product development from polymer development to biomaterial processing and functionalization to prototype production. This also includes cell biological and microbiological testing for function in vitro. The DITF and their subsidiary, ITV Denkendorf Produktservice GmbH (ITVP), are certified according to EN ISO 13485:2016. This enables them to produce prototypes in the cleanrooms of the institutes and the ITVP that can be implanted directly into humans. Finally, if desired, the GmbH also makes its production capacities available. This means that the partners of the DITF and ITVP, who work together on new products, not only have access to the know-how and experience of the institutes, but also to research, development and production that fulfills all current legal requirements and is documented in accordance with the approval.



Go, WannaGo!
Sensor mats to promote movement

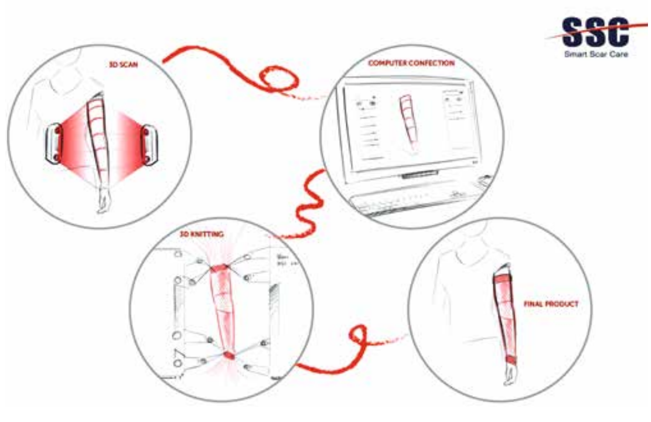
At DITF, many innovations in the field of textile sensors have been advanced in recent years. In numerous areas they are used, from fibre-reinforced composites to the monitoring of vital parameters. In particular, the field of health and care will continue to become increasingly important in the future. In times of home office and advancing digitalisation, people are increasingly lacking movement, whether at work or in their private lives. In the "Go, WannaGo!" project, we aim to get people to move more. Society can be divided into 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 do not for various reasons. These "WannaGos" are addressed in this project and motivated to exercise in the workplace as well as in the social environment by means of new exercise concepts and the associated fun. The sensor mat based on the piezoresistive principle developed at the DITF in cooperation with the consortium partners is intended to provide support here and make movement visible and/or audible. This "joyification" of movement can be achieved through pressure-dependent movements on the sensor mat. Further details about the project and the consortium can be found at www.sinn.international.

Schematic representation of the Company Case

Individualized 3-D compression textiles for scar therapy

From diagnostics to industrial production

Compression therapy using medical compression textiles is an established method for treating scars after a serious skin injury. This type of care places high demands on fit and wearer comfort, which often cannot be satisfied by standardized product sizes. The production of individualized medical compression textiles, on the other hand, is time-consuming and cost-intensive. As part of the BMBF project Smart-Scar-Care, this problem was addressed and a workflow was developed to provide patients with an individualized compression textile for scar treatment within 24 hours. This is done using 3-D scanning to record patient measurements, digital configuration of the product, algorithmic creation of knitting programs, and simulation-based control of compression pressure. This process was successfully tested in the production environment and validated in a clinical study.



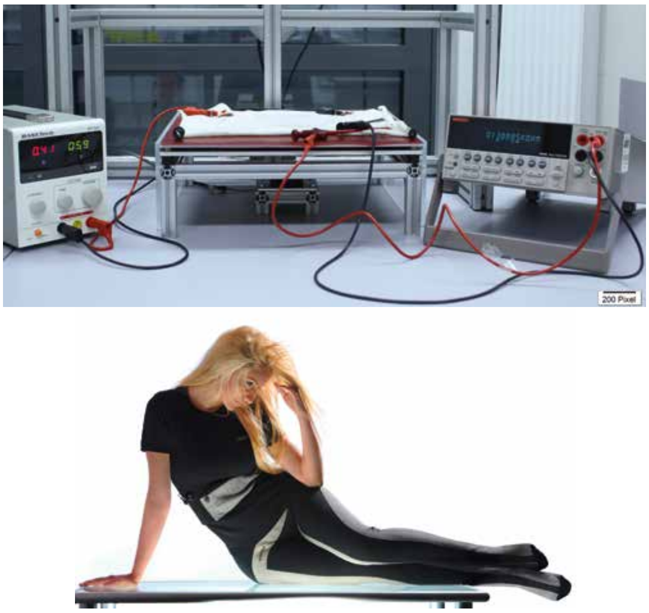
Smart-Scar-Care workflow overview

The project consortium consisted of the companies BSN medical, Karl Mayer Stoll Textilmaschinenfabrik, Avalution and Assyst as well as the University Hospital Schleswig-Holstein and the DITF.

In the project, the DITF participated in the algorithmic generation of knitting programs directly from the 3-D scan and in the thermodynamic analysis of pore systems in materials. As a service, DITF can provide algorithmic interpretation of 3-D models to the knitting program and thermodynamic measurements for materials.

Microelectronics for heated knitwear

In the Ulimpia project as part of the European PENTA cluster, the DITF in cooperation with numerous German and European partners are developing innovative microelectronics, yarns and textiles, among others for vasomotor regulated heated knitwear. The basis are knitted heating areas from WarmX GmbH made of silver-coated polyamide filaments, which are characterized by a pleasant textile feel and can be worn directly on the skin. These heating yarns are combined in knitted structures with sensor yarns that change electrical resistances depending on temperature and thus measure skin temperatures integrally and continuously.



Vasomotor regulated – in the DITF lab (top), the control algorithms for WarmX heated knitted garments are developed (bottom)

During low-activity activities, humans emit body heat almost exclusively as thermal radiation in the mid-infrared, so-called MIR radiation. Characteristically, MIR emission is proportional to the temperature gradient, which means that people do not lose body heat if the ambient temperature is the same as the skin temperature or if the clothing temperature is the same as the skin temperature. The heating power required for this is continuously calculated by a small computer chip based on current skin temperatures and physiological models. In addition to functional clothing, the Ulimpia project is also evaluating medical applications for vasomotor regulated heating textiles.

Combined 3D printing and electrospinning for regenerative medicine

The shortage of donor organs for transplantation could be reduced in the future by using additive processes in the production of artificial organs and the lives of many patients on waiting lists could be improved or even saved. One new possibility is 3D printing as a combination of fused filament fabrication (FFF) and melt electrospinning for cell culture structures in tissue engineering. Scaffolds made using this technique combine high porosity nonwovens made from resorbable polymers with stiffer support structures in a single additive manufacturing process to additively produce microstructures for organoids in one operation.

For this purpose, cell culture structures were 3D-printed from PCL filaments, which contain a melt electrospun nonwoven as a microporous membrane for cell colonization. In collaboration with the University Hospital for Thoracic, Cardiac and Vascular Surgery in Tübingen, these could be seeded with liver cell precursors (hepatoblasts) derived from induced pluripotent stem cells (iPSC). A uniformly covered fiber fleece surface was achieved on which the hepatoblasts adhered and proliferated very well. The Tübingen research team was able to further differentiate these into liver cell-like cells in culture. Thus, this new process, which combines conventional 3D printing with melt electrospinning, can be a step towards additive manufacturing of scaffolds for artificial organs.

Multiwell insert with integrated cell carrier fleece

MOBILITY

The mobile world is changing. Textile innovations from DITF are helping to shape this process. We always keep an eye on the current requirements for comfort, functionality, energy and the environment.

- Smart textiles and weight-saving fiber composites for vehicle interiors and exteriors
- Functional textiles, smart textiles for interior lighting, heating, operation and new appearances
- 3D space winding and tape laying as an extension of existing textile technologies
- Carbon fibers from lignin and cellulose
- Increasing use of bio-based fibers, matrices and additives
- Alternatives to materials that are harmful to health
- Technologies for carbon fiber recycling
- High-quality prepregs made from recycled carbon fibers for load-bearing components
- Complex woven ceramic fiber preforms for Ceramic Matrix Composites (CMC) with high stiffness and thermal shock resistance
- Economical and environmentally sustainable materials for fuel cells
- Textile solutions for hydrogen storage
- Cellulose-based filter materials
- Further development of airbags and protective textiles for ultralight actuators
- Energetic concepts such as significantly reduced energy costs in carbon fiber production, use of microwaves or UV technology

Mobility

Functional textiles and fiber-reinforced composites (FRPs) made from them are successfully applied in the most diverse areas of technology. In addition to pure weight reduction, these materials offer a variety of other advantages, so that the higher price of the materials and manufacturing processes can be compensated. The increasing use of low-cost integral construction, i.e. the manufacture of an FRP component in one shot, enables the embedding of sensors, heating, lighting, the injection molding of connectors/fasteners, as well as the design of a hinge in the fiber composite material. Textile actuators can also be incorporated directly into a fiber composite component, enabling entirely new "dual" lightweight solutions for robotics, for example. Thus, the so-called hybrid (mixed) construction employing steel, aluminum, magnesium and fiber composite plastics is complemented by textiles with integrated smart functions, expanding the portfolio of materials available in mobility.

As a result of the ongoing social discourse on greater sustainability, research is increasingly being conducted not only into high-stiffness/high-strength carbon fibers (with a still high need for research into recycling) but also into the less expensive glass fibers with lower stiffness and, above all, into biobased materials for mobility. Existing applications of biobased materials show that although there is still some need for research, stiffnesses similar to glass fiber composites are already being achieved. In the future, it will be mandatory to evaluate and compare the sustainability of the materials and the components made from them with the specific global warming potential. In the ecological as well as economic evaluation, the recyclability of the components and materials naturally plays a decisive role, so that a great deal of research activity is underway in this area. The wide range of textile technologies available at the DITF makes it possible to provide optimum advice to corporate customers and offers the certainty of being offered the best textile solution in each case.

Improving the range of applications for materials

In addition to research into fibers, textiles for stability and functional integration, the further development of matrix systems is also an important goal of DITF research. For example, thermoplastic matrices such as PA6 with high flame retardancy or even "incombustible" matrix systems that remain stable up to 1,200 °C are being developed. Such matrices are in demand not only in mobility, but also in all areas of application of fiber composite technology due to their high serviceability.

Technology Transfer Program Lightweight Construction (TTP LB)

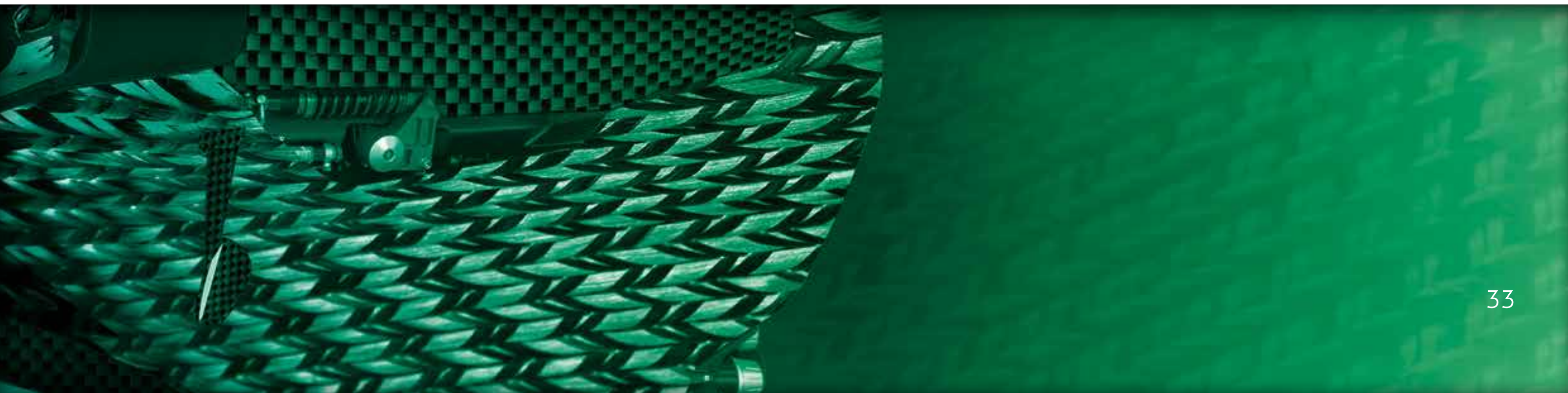
An important innovation driver for lightweight construction in Germany is the Technology Transfer Program Lightweight Construction (TTP LB) of the German Federal Ministry for Economic Affairs and Energy (BMWi), which has been advertised since 2019. There, lightweight construction is counted among the game-changer technologies, which combines an increase in growth and competitiveness while ensuring climate protection and sustainability. Lightweight construction is a design philosophy that focuses on reducing weight while improving resource efficiency and improving or adding functionality. The DITF were able to win 4 projects in this call, which underlines the high competence of the DITF in lightweight construction.

Sustainability and recycling

For improved economic efficiency and sustainability of FRP, residual fibers, textile clippings, pre-pregs, and end-of-life components require large-scale recycling in an environmentally friendly way. On the other hand, the new 3D space winding enables new ultra-light filigree structures. Only with a high recycling credit can the materials exploit their lightweighting potential. Together with the fiber composite and recycling specialists at the DITF, proven experts from the DITF Management Research department are working with complex programs on the globally networked determination of sustainability key data (e.g. greenhouse potential – Global Warming Potential GWP). With these key figures, materials and products can be compared with each other in terms of sustainability, from the extraction of raw materials through production and operation to the reuse of recycled materials.

Transfer of results

An even further exploitation of the positive properties with a very good environmental balance of fiber composites requires overarching research work in the areas of mobility, energy industry, construction, sports and other industries and the highly innovative, interdisciplinary German textile industry. The DITF bring together research and industry and organize workshops and symposia in key research fields and networks such as the Alliance of Fiber-Based Materials (AFBW e.V.), Leichtbau BW and Composite United.



UrbANT: Micromobile vehicles and transport systems for the last mile

Faced with a variety of challenges, such as congestion of existing infrastructures and traffic-related environmental pollution, urban areas in particular are at the beginning of a far-reaching transformation process. The combination of public transport and private transport can cover a large part, but not all, of inner-city mobility needs. This gap in a sustainable and future-oriented urban mobility offer can be closed by suitable micromobility solutions. The BMBF-funded project "UrbANT" (Urbane, Automatisierte, Nutzerorientierte Transportplattform – Urban, Automated, User-Oriented Transport Platform) aims to develop, produce and test an individual, electrically powered micromobility vehicle that enables pedestrians in particular to transport heavy and large-volume goods safely and comfortably.

UrbANT with height-adjustable superstructure

Fiber composite solution

As part of the project, DITF are responsible for the design, development and production of a flexible and height-adjustable superstructure for the vehicle. In addition, DITF are supporting the design of the drive platform and other body variants. To this end, various strategies are being developed for the production of the body's individual components. To meet the lightweight requirements for increasing the vehicle's payload, a telescopic body in fiber composite sandwich construction was designed. In addition, an innovative manufacturing concept based on the tape-laying process was developed in collaboration with the Institute for Textile and Fiber Technologies (ITFT), University of Stuttgart to manufacture a carbon-fiber-reinforced, thermoplastic, flexible rolling door which improves the overall loading ergonomics of the UrbANT.

Pressing technology for thermoformable composites from recycled fibers

Recycled fibers (rCF) obtained in the recycling of CFRP components by means of chemolysis, hydrolysis or pyrolysis are inevitably shortened. These recycled fibers can only compete with difficulty to the mechanical properties of the original continuous fibers, but nevertheless have considerable properties in terms of their weight/performance ratio. For many applications, the superior characteristic values of continuous fibers are not necessary and there is a need for complex 3-D shapes. There, these recycled fibers can find a variety of applications. They can be reprocessed into yarns or nonwovens via textile manufacturing processes. In this project, PA-6 fibers were added to the rCF during processing to have the matrix material already embedded in the textile structure for further processing. The dipping edge tool developed in the project for the demonstrator component includes various chicanes such as strong curves and steep edges. Two different textile structures made of rCF nonwoven and staple fiber fabric were tested for their deep drawability. Both material blends showed very good draping properties, whereby the staple fiber fabric could be formed more permanently. The recycled fibers embedded in a textile structure – staple fiber fabric as well as nonwoven fabric – offer very good deep drawability due to their displaceability and their fiber length distribution and can be pressed via the hot pressing process to form 3-D components, which are difficult to achieve with continuous fibers. The work was essentially supported by process and component simulation, and the development of a material database.

Demonstrator components made of different materials;
from left to right: staple fiber fabric (rCF/PA6), nonwoven fabric (rCF/PP), viscose fabric (CV/CA), nonwoven fabric (rCF/PA6)

Solar thermal active seat cushion for maritime applications

With a new solar-thermal active seat cushion for maritime applications, Wolfgang Bauer of BAUER Yachting and the DITF have succeeded in developing a new lifestyle application that has a lot of market potential. During the day, in the loading phase under sunlight, the upholstery is pleasantly warm, but not hot, and the latent heat accumulator made of phase-change material (PCM) is charged at the same time. In the evening, during the discharge phase, the accumulator releases its heat, warming up the cushion and leading to a high level of comfort.

Solar-thermal active seat cushion: pleasantly warm during the day, but not hot; warming in the evening

For the solar thermal functions, the capture and storage of solar energy was realized through a textile multilayer structure. The seat cushion is made of a weather-resistant fabric as the cover fabric. Spacer fabrics are used for the upholstery and thermal insulation. Heat storage is provided by an integrated textile latent heat accumulator. The high air permeability of the textile layers enables rapid fabric heat exchange. The heat release is promoted by the resulting pressure when sitting and lying down. The required thermally active energy quantity of the PCM was calculated from the specific heat capacity and the desired discharge phase (reheating time) of the seat cushion.

Air can circulate in the seat cushion with 3D textiles. Only a small amount of moisture absorption takes place, so that mold and bacteria cannot develop. Also, the management to the surrounding seawater and the possible penetration by condensation were reconsidered.

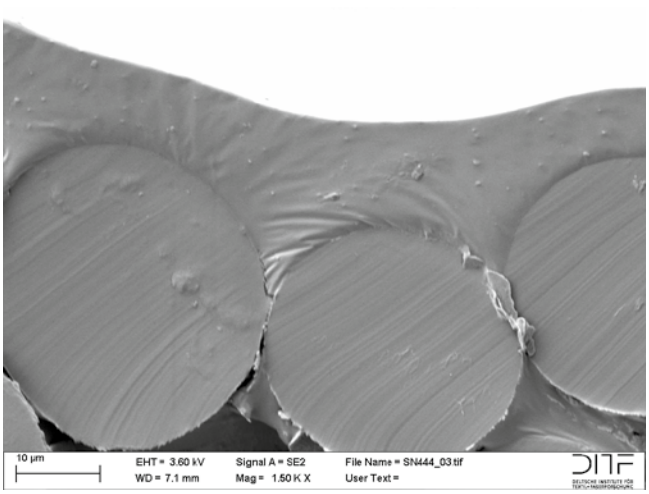
In addition to the maritime sector, other market areas are emerging in the camping and leisure market, where the new functions also lead to an increase in comfort.

Electrically insulating inks

Smart textiles is a segment of textiles that is growing at an above-average rate, and textile products with integrated electronics offer a broad field of activity for SMEs. Here, inkjet printing enables the individual connection of electronic components through printed conductive paths. To ensure that the electronics integrated into textiles function faultlessly and do not cause short circuits, the conductor paths must be electrically insulated. This applies in particular to the digital production of printed electrical circuits.

Insulating layer by inkjet printing

Electrically insulating inks based on binders have been developed that allow electrically insulation of printed conductive paths while maintaining a soft fabric grip. To obtain insulated conductive tracks, the textile substrate must be impregnated or printed with the developed inks before the electrically conductive inks/structures are applied. In a further step, the insulating inks are finally applied in the form of an insulating topcoat. The insulating properties of the ink improve with increasing ink viscosity. Optimum insulating properties are obtained with an ink viscosity greater than 1 Pas. In the case of low-viscosity inks, multiple printing of the insulating layer on textile structures is required, while the insulation of metallic 2-D layers investigated as examples can already be insulated with a single printing.



SEM image of a printed electrically insulating layer

ENERGY, ENVIRONMENT AND RESOURCE EFFICIENCY

The DITF institutes develop processes and systems for improved energy, environmental and resource efficiency – with and for their industrial partners. The results are sustainable products and services for a variety of applications.

- High-performance fibers from biopolymers
- Carbon fibers from cellulose and lignin precursors
- Coatings and finishes from renewable raw materials
- Sustainable polymer syntheses to replace pertro-based monomers
- Analysis of biodegradation in water, soils and reactions
- Solvent-free, energy-saving processes for coatings and textile finishes
- Minimal application technologies
- Heat recirculation and heat recovery in dryer systems
- Use of artificial intelligence for good parameter setting of finishing machines
- Textile-based thermal solar collectors
- Energy generation through the use of technical textiles
- Economical and environmentally sustainable materials for fuel cells
- Textile materials for the extraction of drinking water from fog
- Irrigation systems based on particularly high capillary forces and suction power
- Filter materials for separating gases/solids/liquids
- Recycling technologies for high-performance fibers

Energy, environment and resource efficiency

Fibers have always been crucial components of nature. Especially in the plant kingdom, nature utilizes the properties of fibers to build a wide variety of structures and functions. Thus, it is not surprising that fiber-based materials hold many compelling and sustainable solutions for the requirements of lightweight construction, energy efficiency and storage, resource efficiency, as well as environmental protection. Even though they are often invisible in the background and go unnoticed, fiber-based materials are indispensable to solving the problems in these fields of the future since they act as catalysts for increased efficiency, environmental protection, and reduced environmental impact.

Due to the increasing importance of the research field, the DITF are bundling the research capacities and know-how of different areas in two new competence centers, the Competence Center for Biopolymer Materials and the Competence Center for Textile Chemistry, Environment & Energy. The development of processes and systems for improved energy, environmental and resource efficiency – with and for their industrial partners – make the DITF essential research partners in this area. The results are sustainable products and services for a variety of applications. Sustainable high-performance fibers, new biopolymer materials, filter and membrane materials for air and water purification, lightweight construction, insulators, sealants, as well as insulants for buildings and textile-based solar cells are just a few examples of the broad research portfolio at the DITF institutes. Current research topics focus mainly on material substitution, material efficiency, use of artificial intelligence, biodegradation and recycling.

Renewable energy sources, energy systems

Technical textiles in Germany owe their success to the continuous development of new areas of application. Of particular interest in this context is the extraction of energy through the use of technical textiles, which is the subject of intensive research at the institutes in Denkendorf. Successes can be observed in solar thermal energy and thermal energy storage as well as in combinations thereof. Further developments include the recovery of heat energy from wastewater through novel heat exchangers, along with resource-saving and economical novel materials for hydrogen technologies, as well as new electrical energy storage systems. Recent work deals with safety and environmental aspects of solar cells using biopolymers. Another significant contribution of fiber-reinforced composites is in the development of wind turbine blades.

Textiles for environmental protection

In the meantime, technical textiles significantly contribute to the mastering of environmental protection-related tasks in many industries. Accordingly, our research efforts include new filter systems, such as filters to extract particulates and pollen from the air, as well as isolate aerosols in cold and hot flue gas streams. We also develop textile supporting materials for biological organisms in vertical greenery, sewage treatment plants, and algae production. Currently, we are working on new irrigation and water storage systems for greenhouses and sports turf to improve plant growth. The advancement of acoustic absorption in the home and mobile sector continues to be a research topic.

The application of membranes in the wastewater treatment of the textile industry, as well as other manufacturing companies, has been a focus for years.

Sustainable fibers and composites

The sustainability of textile products is a central issue in our society and is currently undergoing a strong collective change. Given the discussion on microplastics in surface waters and oceans, our research on natural fibers and polymers from renewable resources, which are also readily biodegradable or recyclable, is of vital importance for the future. Natural fibers from wood, hemp or algae play an enormous role in the production of textiles and their ecological and economic recycling. Further work includes the processing of natural fibers into high-performance yarns using state-of-the-art technology as well as the development of new filter materials and composites made of cellulose and chitin. New cellulose-based reinforcing fiber types have been developed for these composites via HighPerCell® technology.

The production of cellulose composites creates lightweight, stable, aesthetic products that can be recycled or processed bioenergetically and lead to an overall reduced carbon footprint. Our research focuses not only on various modern manufacturing processes but also includes product cycle analyses and how these affect the properties of the materials.

Self-healing materials that regain their properties after damage constitute a relatively new branch of bionic developments. Initial approaches employing particular filled hollow glass fibers in composites have yielded promising results.

Often, these developments are accompanied by a life-cycle analysis to quantify both the consumption of our natural resources as well as the impact on the environment.

Energy consumption in textile manufacturing

Textile finishing and coating constitute the most energy-intensive processes in textile manufacturing. Thus, there is a need to review new technologies for their energy-saving potential. Such review includes the commissioning of cross-linking systems of solids without solvents and reactive hot melts, the use of minimal application technologies such as foam application methods, and innovative pretreatment methods based on ultrasound.

Additionally, we are exploring the further development of dryer systems with more efficient heat-material transitions, heat recirculation, and heat recovery, as well as smart process control systems using artificial intelligence methods. New ways of interconnecting equipment and coatings result in energy savings in drying and achieve excellent properties. These include curing through the use of electron-beam technology and ultraviolet light based on LED.

We achieved notable success with atmospheric- and low-pressure plasmas, which find increasing application in textile manufacturing.

Processing of recycled carbon fibers into hybrid yarns – Determination of the influence of spinning technology

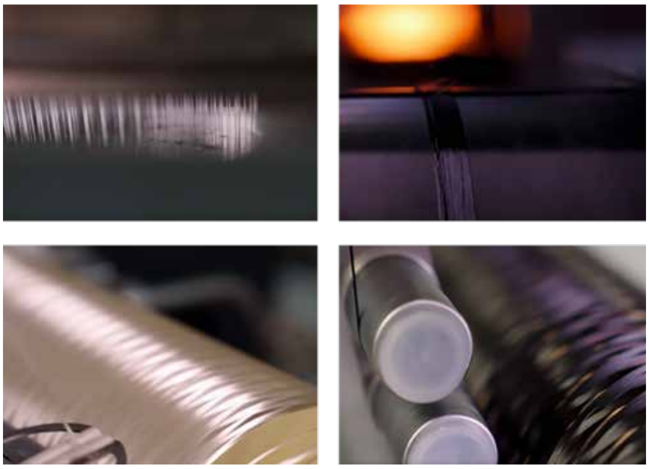
In the joint project CarboYarn of the Institute of Textile Technology (ITA) of RWTH Aachen University, the German Institutes of Textile and Fiber Research (DITF) and ITA Augsburg, the research team investigated different spinning processes such as ring spinning, rotor spinning, friction spinning, and wind-around spinning for the processing of recycled carbon fibers (rCF). For this purpose, the entire recycling process was considered, from the rCF in different makeup (production waste and pyrolysis fibers) to fiber preparation and blending with matrix fibers, sliver formation, and spinning process to the consolidation of CFRP test specimens. As a result, the rCF could be successfully processed into hybrid yarns in combination with polyamide-6 fibers. Unique yarn structures typical for the respective process could be produced with almost all spinning processes. Only rotor spinning was unable to produce hybrid yarns. The rCF composites produced were finally examined with respect to tensile and flexural strength. The influences of the yarn structure were visible. An economic evaluation carried out during the project showed that an economical production of rCF hybrid yarns is possible independent of the type of spinning process.

Products of the individual recycling process steps in the CarboYarn project

We gratefully acknowledge funding via the Textile Research Board as a member of the German Federation of Industrial Research Associations (AiF) from budget funds of the German Federal Ministry for Economic Affairs and Energy within the framework of the Program for the Promotion of Industrial Cooperative Research (IGF) 19814 N.

HighPerCell® – New cellulose filament yarns for technical applications

A novel process for the production of high-performance cellulose fibers from wood pulp has been developed at DITF. Thanks to the patented HighPerCell® technology, this new type of regenerated cellulose fiber is an environmentally friendly alternative to the industrially used viscose process. HighPerCell® technology relies on the use of a new type of solvent called ionic liquids (IL). These are considered to be ecologically and in terms of safety harmless, as they are neither toxic nor flammable. Furthermore, they are characterized by good mass efficiency due to their easy and almost complete recycling. These aspects make ionic liquids optimal solvents for large-scale technical applications in terms of a sustainable circular economy.



Pictures from the spinning and carbonization process

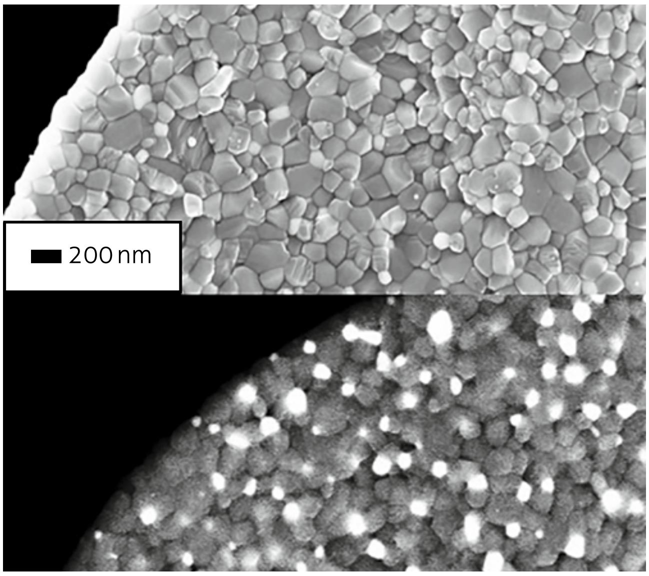
From tree to high-performance material

DITF fibers are characterized by high strength. The chemical structure of the cellulose enables good dimensional stability of the fibers. Due to these properties, HighPerCell® fibers are predestined for use in technical applications. Possible applications range from reinforcing materials in composites to the production of carbon fibers (HighPerCellCarbon®) with outstanding material properties. Carbon fibers made from cellulose are a cost-effective and environmentally friendly alternative to non-sustainable petroleum-based carbon fibers. The next step will be the technical implementation of the HighPerCell® and HighPerCellCarbon® process in cooperation with the newly founded Technikum Laubholz GmbH.

New mullite-based ceramic fibers for high-temperature lightweight construction

Ceramic fiber research at DITF has further successes to report. As reported last year, in addition to the production of the "standard fibers" based on alumina (OxCeFi A99) and mullite (OxCeFi M75), new fiber types are also being developed. Adding to the fiber made of zirconia-reinforced alumina (OxCeFi ZTA) presented last year, the production of a new fiber type made of zirconia-reinforced mullite (OxCeFi ZTM) has now been researched and technically implemented from scratch. The mullite-based fibers represent the top class of oxide ceramic fibers in terms of temperature resistance. By incorporating (3-15 wt.%) zirconium oxide into the fiber structure, further improvements could be achieved regarding the mechanical properties of the fibers. This represents an absolute novelty and accordingly a patent application has been filed for this invention.

The aim of the developments at the DITF is to further improve the performance of ceramic fibers in the high-temperature range. The fibers are the essential component in ceramic fiber composites (OCMC: Oxide Ceramic Matrix Composites), which are gaining increasing importance in high-temperature lightweight construction in the fields of aerospace engineering, energy technology, chemical process engineering and industrial furnace construction. An important criterion here is that these non-metallic materials can be manufactured very resource-efficiently.



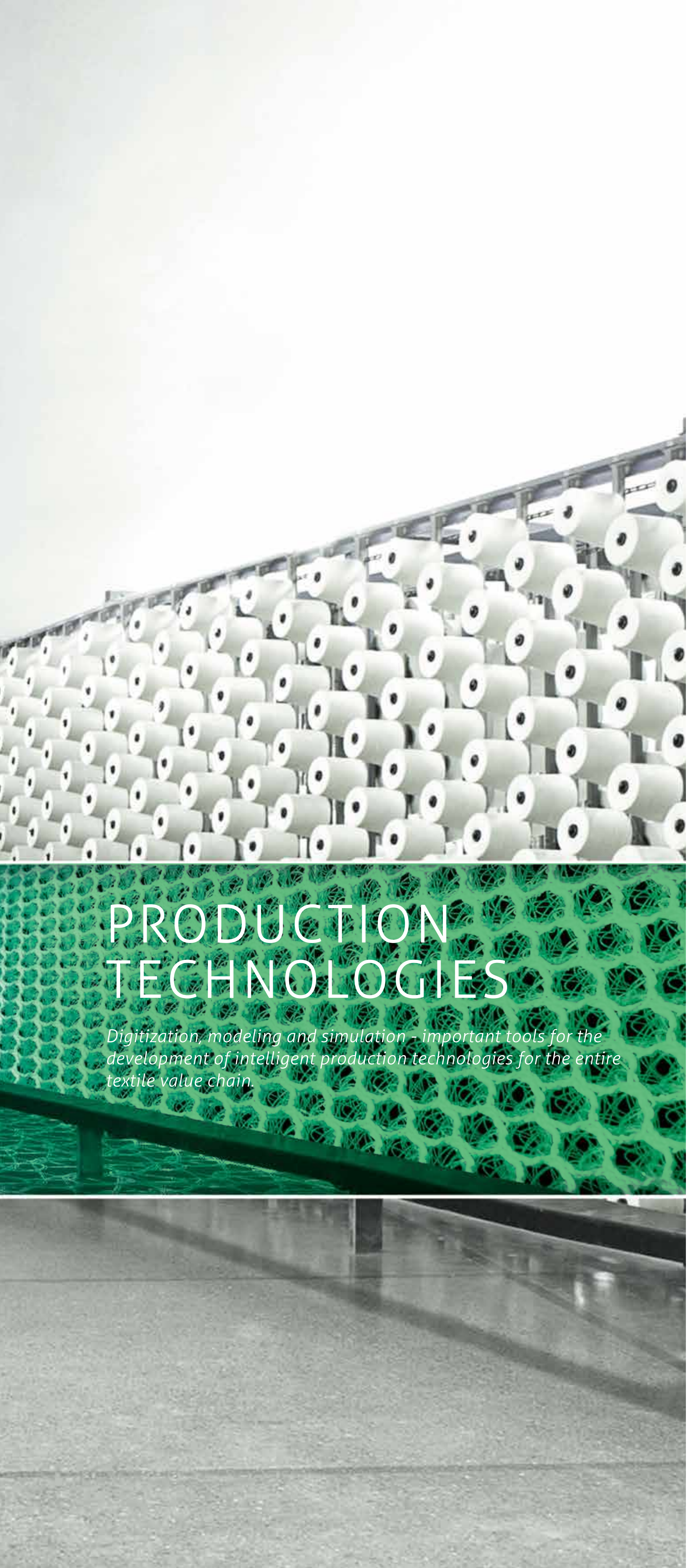
ZTM15 fibers after therm. aging at 1,400 °C for 10 h
(SEM with backscattered electron image for comparison)

Recycling of carbon fibers with a matrix of polypropylene and adapted sizing agents

The use of carbon fiber reinforced fiber composite (CFRP) components is growing steadily. Accordingly, recycled carbon fibers (rCF) are already being produced and will be produced to a strongly increasing extent in the future. The rCF from pyrolytic and solvolytic reprocessing still possess essential usable properties of the original fibers. However, in contrast to virgin fibers, they are not available as continuous fibers, but as short and long fibers and with a more undefined surface condition. The fiber surfaces must be treated accordingly with a sizing agent. It acts as a lubricant and at the same time as an adhesion promoter, so that the carbon fibers can be processed industrially and high strength results in the new fiber composite component.

Fleece formation process

Technically challenging, but with high application potential, is the processing of rCF with polypropylene (PP) into thermoplastic fiber-reinforced composite components. The main challenge is that both components, matrix PP and carbon fiber, are chemically non-functional. Sufficient fiber-matrix adhesion results only if both the carbon fiber surface and the polypropylene are well matched. For this purpose, the project developed sizing agents with proportions of maleic anhydride (MA), which were applied to the rCF. The MA was also blended into the polypropylene from which fibers were spun out. A blended nonwoven was prepared from both fibers. Test panels were pressed from the nonwoven under the influence of temperature. Mechanical testing showed that the addition of adhesion promoter into the fiber provided higher strength values than via sizing on the fiber.



PRODUCTION TECHNOLOGIES

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

- Smart process control systems
- Digital technologies for Industry 4.0
- Microfactories for digitally networked production
- Functionalization of textiles with modern technologies
- Systems to bridge human-machine interaction
- Modeling and simulation of processes as a basis for effective process optimization
- New processes for the production of printed sensors and actuators on textile

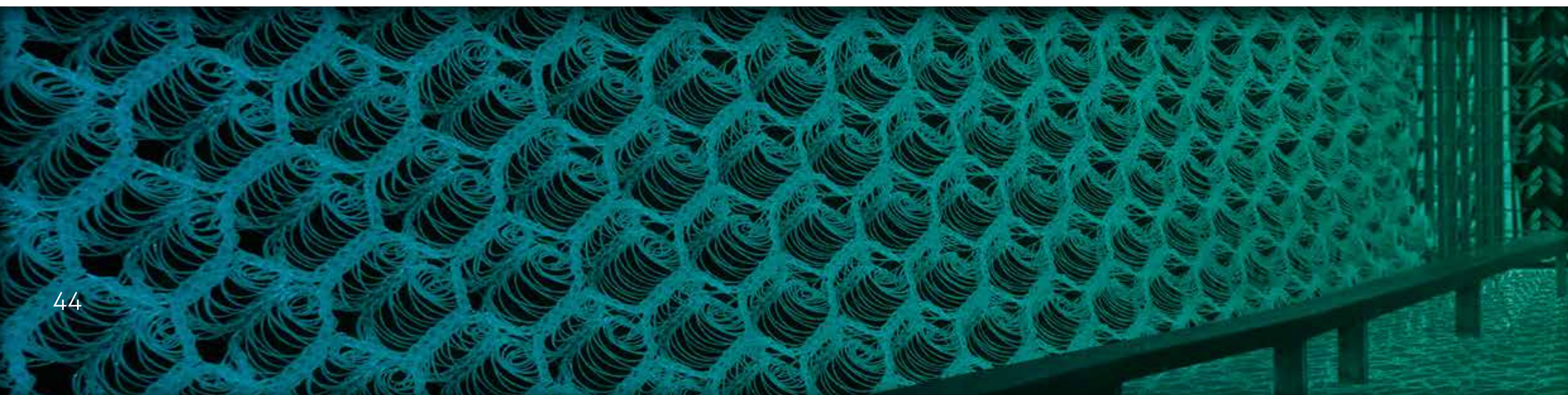
Production technologies

In the light of global competition, innovative approaches in the field of textile production technologies are needed more than ever. Under the aspects of sustainability, resource conservation and recyclability in the manufacture of textile products, the technologies for the production of such products must also be adapted and optimized.

The DITF are the leading partner not only in the fields of textile process engineering and textile and fiber chemistry, but also the preferred development partner for non-textile companies that see the advantages of fiber-based materials in new fields of application. Whether in architecture and construction, in health and care, in mobility, in energy, environment and resource efficiency - these materials are used everywhere and are, for example, an important component of modern lightweight construction concepts. Roughly a third of the DITF research projects encompass production technologies, which make up the most substantial portion of applied research. In this context, digitization, modeling and simulation are becoming increasingly important for the development of intelligent production technologies across the entire textile value chain.

Interdisciplinary networking and collaboration as the key

The development of new process engineering and process technologies is effective when knowledge is available along the entire manufacturing chain. This is why the DITF have been conducting research along the entire textile manufacturing chain for decades, starting with the synthesis of fiber polymers, through spinning processes and textile surface production to the manufacture of prototypes, and can draw here on the experience of longstanding employees. They use the know-how of experienced specialists in the individual process stages to achieve the optimum result for the customer. The focus is on the holistic approach that takes into account all areas such as technical, textile technological and economic aspects. The basis for this is the interdisciplinary cooperation of experts from various fields such as textile technology, mechanical engineering, process engineering, chemistry, physics, biology, cybernetics, computer science or economics.



Applied research on 25,000 m² of space

Applied research and development are only possible if appropriate industry-related equipment is available. With an area of 25,000 m², the DITF have the prerequisites to maintain, further develop and newly build production technologies in order to conduct research close to industrial reality. We can also cater for pilot or small productions. We develop and build prototypes in-house. Production processes for the manufacture of fiber-based composites, 3D textile structures, digitally printed textile structures, high-performance fibers, etc. are available under one roof and can be used and modified according to customer requirements.

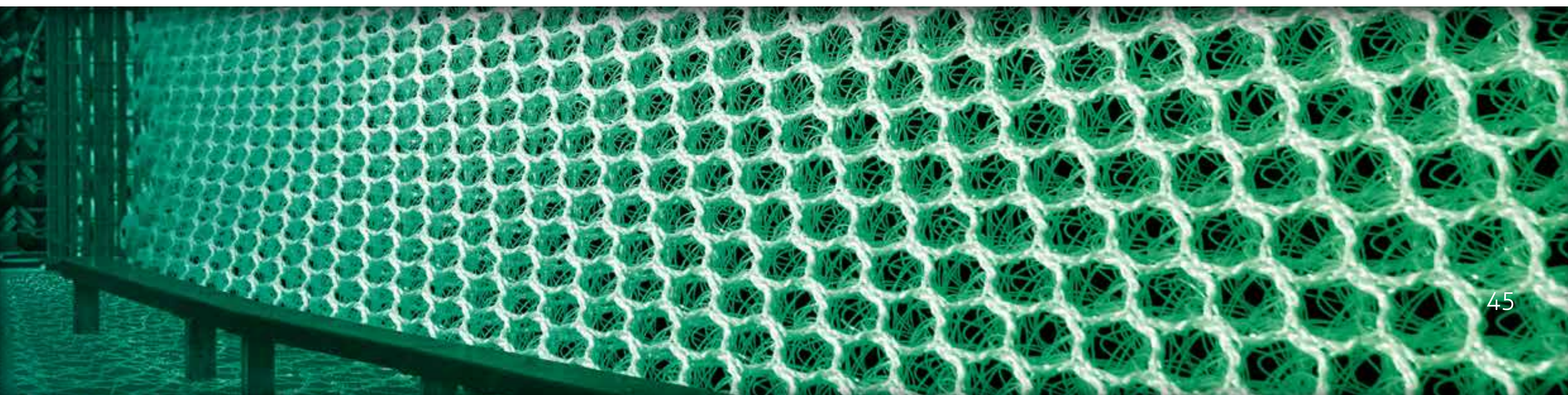
We also support partners in the area of electronics and control. A state-of-the-art workshop and electronics laboratory serve specialized technicians to implement new ideas into testing and production procedures of the textile industry.

What will the future bring?

The buzzword "digitization" will also determine the future of textile process engineering and production technologies. German and European textile machinery manufacturing certainly does not have to hide in this respect, as digitization is well advanced in modern machines. However, the requirements of Industry 4.0 do not only relate to individual machines, but to complete production processes, such as those implemented in the Microfactory of the DITF. Here, everything is digitally networked and documented, from the digital recording of body measurements, to computer-aided pattern making, to digital printing, to cutting for the manufacture of apparel textiles. For such production processes, the Textile 4.0 multifunctional laboratory of the DITF offers state-of-the-art process and IT infrastructure.

Not all processes have to be studied experimentally at great expense. Modern modeling and simulation tools allow pre-development on the computer, which limits the subsequent experimental effort and thus enables fast, targeted development.

For the process engineering developments of the future, considerations of sustainability, resource conservation, energy minimization and the recyclability of products are of decisive importance and must be seen as guard rails within which we must move.



New Textile 4.0 Multifunctional Lab

Digital engineering and digitally networked production are central concepts of Industry 4.0, which have been developed in recent years at the Center for Management Research for the textile and apparel industry and exemplarily realized at leading trade fairs in the form of microfactories. The opportunities offered by this are leading to a changed strategy discussion worldwide with a focus on nearshoring, regional production and digitally networked supply chains.

Through external funding and our own financial efforts as well as content-related work, a Textile 4.0 multifunctional laboratory was created at the DITF. In addition to the microfactory approach, many research topics related to digitization find their place in this modern, flexible environment.

New Textile 4.0 Multifunctional Lab at the DITF

For the construction of the lab, the DITF provided approx. 160 m^2 of space, which was equipped with completely new infrastructure as part of an investment project for the new use. Investments of about 750,000 € were made, 500,000 € funding in the program "Zwanzig20 – Partnerschaft für Innovation" of the BMBF and about 250,000 € own funds. In addition to these figures, building in existing structures was a real challenge for all involved. However, the result after two years of intensive preparatory work and construction now meets all requirements.

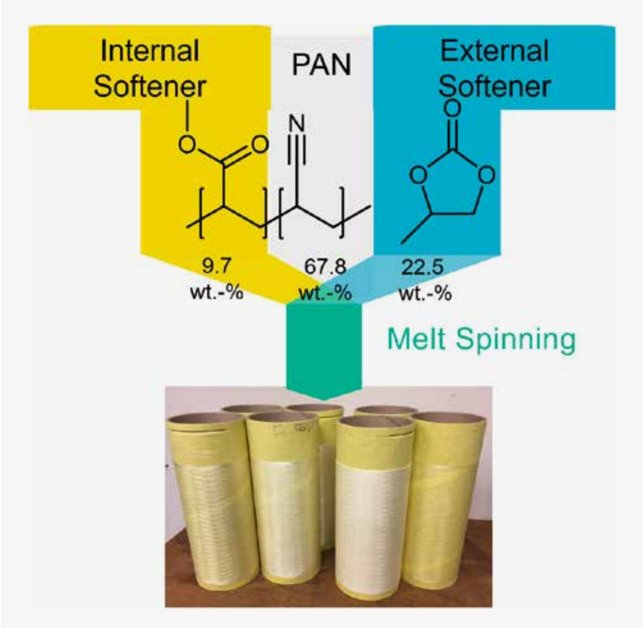
The construction of this multifunctional laboratory enables the DITF to work on central research topics of the future with a focus on digitization together with partners. The DITF's focus on end-to-end digital engineering for individualized products in microfactories and agile manufacturing systems is the result of many years of successful research and development partnerships, which will be further expanded with the new laboratory.

Development of a novel melt spinning process for the production of polyacrylonitrile fibers

In this industrial project with Dralon GmbH as a partner, a new method was developed in which polyacrylonitrile (PAN) fibers can be produced via a melt spinning process without the use of solvents of concern.

For this purpose, a PAN was synthesized with the comonomer methyl acrylate (MA) as internal plasticizer and melt-spun with the toxicologically safe solvent propylene carbonate (PC) as external plasticizer, which can then be removed in a water bath. Using an experimental matrix and supported by rheological measurements, a PAN with suitable comonomer content and molecular weight range was identified. The required amount of PC was determined by means of laboratory-scale spinning trials.

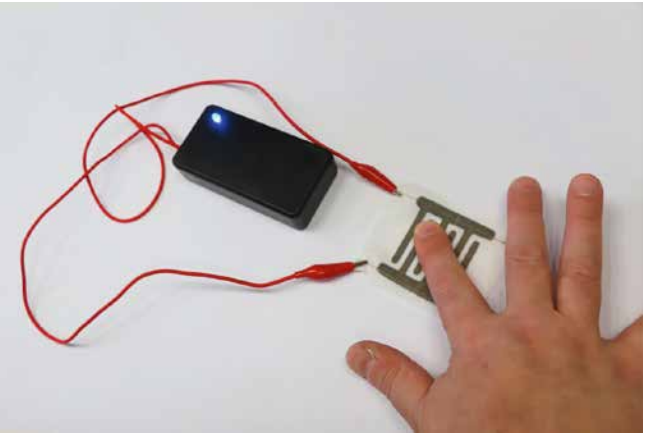
The spinning process could then be scaled up to the kilogram scale. The textile mechanical properties of the produced fibers are comparable to commercial PAN fibers for textiles. It was also shown that a comonomer with a flame retardant function, for example dimethyl phosphonomethylacrylate (DPA), can be used instead of MA as an internal plasticizer in this spinning method.



Schematic representation of the melt spinning process carried out for PAN

Electrical contacting

Low-resistance electrical contacting by printing processes has still not been realized for the rapidly growing market of smart textiles. Conventional contacting processes usually make use of electrically conductive adhesives, which either have a high contact resistance or lack elasticity at the contacting point.



Highly conductive printed interdigital structures/sensor by laser sintering

Laser sintering of metal dispersions

As part of a research project, low-resistance contacting was developed by laser sintering of printed silver dispersions. For this purpose, metal dispersions based on silver were printed onto the contacting point and converted into a low-resistance and flexible thin conductor layer by suitable laser treatment. Both appropriate inks for contacting and the parameters of laser sintering were developed. The contacting points and conductor paths produced in this way can withstand up to 10,000 bending stresses without damage.

In a further project, other and less expensive metal dispersions are now to be investigated with regard to the contacting and production of conductor tracks by laser sintering.

3D-GewebeSim

As part of the project "Simulative investigation of the design potential of jacquard multilayer fabric technology – Virtual Testing" – 3D-GewebeSim – the weaving and simulation departments are working together to develop a process chain for creating and testing virtual 3D fabrics. The program "3D Weave Composite" from the company EAT GmbH is first used to create the weaving pattern for the 3D fabric. The software makes it possible to qualitatively assess and modify the yarn course in a schematic 3D representation. However, this representation is far from reality. Therefore, a simulation based on the finite element (FE) method is developed, which in a further step transforms the abstract weaving pattern into a geometrically realistic fabric representation. For this purpose, the yarn course of the monofilament representation is exported from "3D Weave Composite" and converted into a multifilament FE model using a program developed in the project. The realistic fabric representation is achieved by a targeted expansion of the multifilament threads in radial direction and a targeted contraction in axial direction. The virtual 3D fabric obtained in this way can then be converted into an FE model for computing mechanical properties in the fiber-plastic composite by software currently under development. This provides a virtual testing and analysis process for the load-adapted creation of 3D fabrics, which can qualitatively predict the product properties and reduce essentially previously required iterations for the development of 3D fabrics.

Generation of the meso-model of a 3D fabric

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 and competitiveness

All environmental, economic, and social aspects of sustainability are gaining importance. Keywords such as "circular economy", "sustainability" or "life cycle analysis" are now part of the daily vocabulary in the textile industry. Our expertise makes us part of the European initiative to create a broad network of companies in the textile industry with laboratories for innovation, service providers, and business consultancies and to provide alternatives to excess production and depreciation. This offers the opportunity – also due to Covid – to initiate a relocation of production capacities back to Europe and to improve resilience. These include new strategies for the reuse of often high-quality fiber products through appropriate fiber preparation or chemical recycling. At the same time, however, the use of fibers or coating materials from raw materials available from biogenic or renewable sources is also required. As renewable raw materials, cellulose, chitosan/chitin, alginate or, more recently, hyaluronate have been the focus of the DITF for several years. In the case of coatings, biogenic (partially) based polyurethane or polyurethane acrylate coatings are the focus of interest.

New finishes for antimicrobial properties

The development of textiles with antiviral function has taken on a completely new dimension with the Corona crisis. Since March 2020, the DITF have been working on the development of possible concepts for corresponding protective equipment, both for the clinical and private sectors. In several projects, methods are primarily being investigated here that achieve rejection and/or killing of germs by equipping them with physically based methods. In parallel, the reuse of protective clothing is an important topic. A large proportion of these textiles are made of synthetic fiber material such as polypropylene or polyester. They end up in the trash or in the environment after mostly one-time use. Here, the DITF are developing new solutions for the appropriate finishing and use of natural fibers.

Innovative dyeing processes for high-performance fibers

Today, high-performance fibers are an important mainstay for many domestic textile companies in the production of high-quality articles, especially in the field of protective clothing. Unfortunately, high-performance fibers such as aramids cannot be dyed as easily as cotton, polyester or other commodity fibers due to their structural properties. Over the past five years, the DITF have succeeded in developing a process for dyeing aramids in close cooperation with medium-sized textile companies.

Surprisingly, aramid fibers can be dyed with vat dyes with high lightfastness and, above all, carrier-free. Urea can be used as an alternative to the usual carriers, most of which have a high hazard potential for humans and the environment. The process can also be combined with vector protection or NIR finishing.

Digital printing

Digital application processes have developed rapidly in recent years and thanks to their high flexibility and productivity, it is no longer possible to imagine the textile industry without them. They enable design changes at the touch of a button, no time for setting up the printing machine and allow continuous operation at printing speeds of more than 40 m/min while maintaining the highest level of quality. That is today's digital printing.

The DITF have been involved in this technology for many years and have made a significant contribution to the current state of the art through their wide-ranging research work in this field. The research work includes trend-setting developments in the field of fabric pretreatment as well as UV-curable color inks, which can be fixed in a particularly energy-saving way. Increasingly, current research activities are focusing on the development of inks for the digital finishing and functionalization of textiles. The printing of invisible security markings (plagiarism protection) has also been realized, as well the digital printing of electrical switches and heating elements, as well as printed light.

Continuous digital engineering and micro-factories

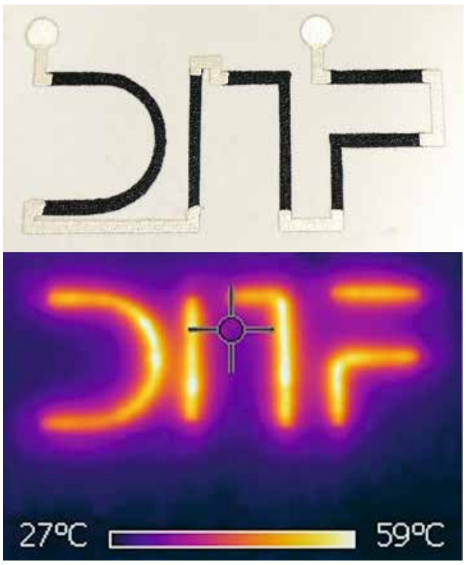
Digital technologies change the competitive environment and offer new chances to companies working in the apparel and household textiles industry. The DITF institutes have several laboratory and demonstration environments to show firsthand what digitization makes possible. The DITF showcase also presents "Digital engineering" at the Mittelstand 4.0-Kompetenzzentrum "*Textil vernetzt*", (competence center for mid-sized companies, "networked textiles"). It is a digital process chain in the area of clothing and home textiles. Continuous digital engineering from design to the final product is a milestone in digital transformation not only from a technical perspective. Fully integrated, automated digital process chains make even entirely new business models exciting and lucrative. They save material costs, development times and permit a swift but also flexible reaction to changes in the markets. It does not matter if they are micro-factories for regional or urban production of small batches or custom and unique individualized items – all of them address current market trends. Micro-factories also have substantial ecological advantages compared to conventional processes. The DITF with their Textile 4.0 multifunctional laboratory bring the newest technology for digitally networked development and production processes to customized enterprise solutions.

Printed electronics/flexible protective layer – Use of a screen printing carousel for textile functionalization

Printing processes are particularly suitable for the textile integration of sensors or actuators with complex geometries. Printed sensors often consist of several layers that must be precisely positioned relative to each other in order to ensure the functionality of the sensor on the one hand, and on the other hand to affect the intrinsic properties of the textile as little as possible. For this reason, textiles are functionalized at the DITF using a screen printing carousel. The screen-printing process applies a large amount of printing paste to the textile. This ensures the functionality of each layer. By using three printing stations whose positions are coordinated with each other, the different functional layers can be printed precisely and efficiently.

In this way, dispersions developed at the DITF could be applied homogeneously. The resulting flexible protective layers exhibited particularly high rub resistance. Among other things, they were used in a five-layer print buildup to produce a heating textile.

In another research project, the screen-printing process is being used to produce a printed proximity sensor. Here, the sensitivity of the sensor is significantly increased by the use of a measuring electrode, a shield electrode and several insulating protective and separating layers. The geometries of the five to six printed layers are precisely positioned to each other. This improves the sensitivity and at the same time the mechanical as well as chemical resistance.



Heating textile with five-layer print buildup

New flame-retardant coatings with phosphorus celluloses

The demand for flame-retardant materials continues to increase, in the textile industry mainly for protective clothing or uniform fabrics. But flame-retardant textiles are now also standard for textiles used in the public sector, for example in means of transport (motor vehicles, trains, aircraft), or public buildings. However, there are increasing legislative restrictions on the use of flame-retardant chemicals. Many of the highly effective flame-retardant substances previously used have now been banned for toxic, health or environmental reasons. Developing new high-performance products in Europe and bringing them to market has therefore become almost impossible.

Cellulose phosphite coating after intumescence, coated substrate underneath is largely preserved

Since polymers are not subject to REACH, the strategy pursued at the DITF is to focus on flame-retardant biopolymers for the necessary new developments. In the meantime, it has been possible to produce new phosphorus-containing polymers with which textiles can be coated in a water-based process. The key point here is the synthesis of a flame-retardant derivative from the renewable raw material cellulose. The reaction itself is based on the reaction of cellulose with phosphorous acid and urea – starting materials that are very favorable.

A wide range of applications opens up for the coatings, from woven fabrics and nonwovens to yarn coatings.
In special cases, even intumescent coatings can be produced, which are often extremely heat resistant according to experience.

Virtual technologies in digital collection development

The digital transformation continues to advance in the apparel industry and offers great potential – from virtual product development to the direct involvement of customers and retailers. With a focus on the collection development and production process, the DITF is researching precisely this. With the Digital Textile Microfactory, it has already been successfully demonstrated at trade fairs how a production line can be implemented in a continuous and digitally networked manner from the 3D simulation through the various production stages to the finished product. But digital solutions are also needed in established value chains and especially in the sales process in order to be able to react to trends as quickly and effectively as possible. The DITF developed new solutions for virtual (VR) and augmented reality (AR) in the retail industry, in which feedback processes from consumers, retailers and manufacturers are digitally and virtually supported. For example, the real shopping environment at the point-of-sale is additionally virtually extended to visualize garments on avatars via AR. In this way, customers as part of the overall process help retailers to create an assortment that meets their needs and manufacturers to develop collections that are specific to their target groups. In the B2B sector, apparel retailers and manufacturers use VR glasses to exchange ideas about prototypes and future collections. Due to the COVID-19 pandemic, a completely virtual concept was developed for this purpose in order to continue to enable digital transfer. In this context, DITF provides apparel retailers with a pre-configured VR system environment so that the VR session can be used by multiple users in a virtual showroom, regardless of location.

Feedback on the collection with the help of virtual reality glasses

Individually adjustable fabric preparation for inkjet printing

The application of a low-viscosity inkjet ink places very high and specific demands on the pretreatment of the printed goods. Without suitable fabric impregnation, the ink would penetrate very strongly into the substrate and bleed out, resulting in blurred contours and poor color yields. Up to now, available fabric pretreatments are mainly based on empirical values and often do not meet the requirements. What is needed are specific pretreatments that can be individually adapted to the physical-chemical properties of the printing inks used and that ensure optimum wetting of the ink.

Inkjet printing

Wetting properties are decisive

For pretreatment, the concept of specifically adapting the wettability of the substrate to the surface tension of the printing ink by means of surface-active substances was developed, and methods for characterizing the substrate properties and the resulting print image were worked out. Inkjet pretreatment consists of at least two complex pretreatment systems with different surface tensions, which, when mixed, enable an individually adjustable pretreatment level with a defined surface tension. As a result, the substrate properties are optimally adapted to the printing inks, obtaining perfect color and contour qualities.

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 Economics, Labor and Housing.

The supervisory body of 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 Economics, Labor and Housing 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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Since its founding in 1961, the Association of the Sponsors of the German Textile and Fiber Research Institutes has supported business-related research and development at the DITF. Currently, 35 members from industry and textile industry associations are involved in the association. The development of new technologies is supported and innovative preliminary research is financed through their membership fees and donations.

In the last few years, funding went mainly to individual projects, such as the expansion of the textile laboratory, investment in a vacuum hot press, a 3D flat knitting machine and in equipment and test equipment for the development of high-performance fibers. These investments in the infrastructure of the DITF directly benefit business, especially SMEs.

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Promote application-oriented research and development at the DITF and co-design the textile future!

Contact: Peter Steiger, peter.steiger@ditf.de

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