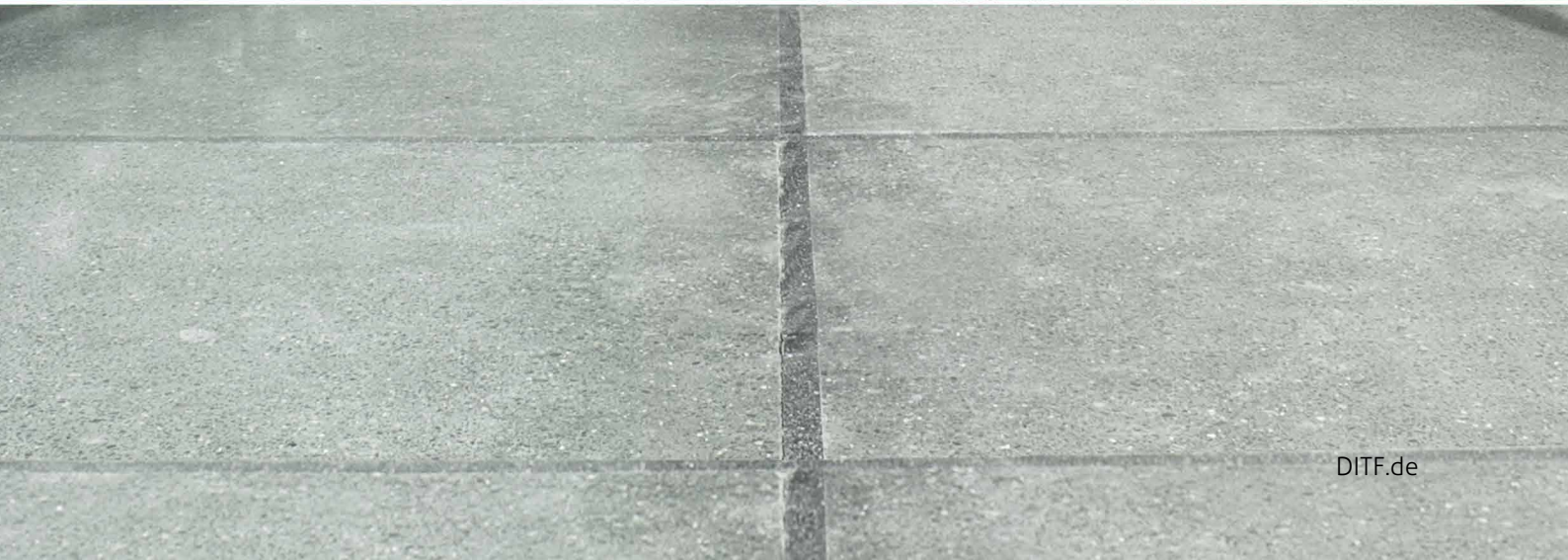
DITF

DEUTSCHE INSTITUTE FÜR
TEXTIL+FASERFORSCHUNG

ANNUAL REPORT 2017

TEXTILE FUTURE



DITF.de

OPEN THE WINDOW INTO THE WORLD OF TEXTILE

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

DEUTSCHE INSTITUTE FÜR
TEXTIL+FASERFORSCHUNG

ANNUAL REPORT 2017

FOREWORD

Dear readers,

2017 has been a transformative year for the German Institutes for Textile and Fiber Research Denkendorf (DITF): The DITF strategy for 2021 resulted in a new brand structure. The four individual Denkendorf brands were merged into one strong brand. ITCF, ITV as well as DITF-mr have been replaced by the concise and straightforward DITF – German Institutes for Textile and Fiber Research. Accordingly, we also gave the brand a new appearance, including a new logo and a new corporate design.

Thus, the complicated public image of four brands has given way to a compact and modern appearance that expresses what we stand for today. "Textile Future" offers great potential, a message we intend to communicate more clearly. The textile world shall become tangible. We were able to present our new appearance just in time for Techtextil 2017, the leading international trade fair for our industry, and received a wave of positive feedback from our customers and partners.

Textile 4.0 – Shaping digital change

Change and complete reorganization were also the focus of numerous projects within the Textile 4.0 framework. As one of the fields of the future with the most significant dynamic development and cross-industry importance, the digital transformation toward Industrie 4.0 carries far-reaching implications for the textile and clothing industry. The DITF actively contribute to the digital transformation of the textile industry covering the entire process chain; we can confidently promise that "We are digitizing the textile industry".

Three Denkendorf projects, in particular, achieved broad visibility and attracted considerable interest: The Strick 4.0 study, which outlines the future of textile production using the example of the cluster of excellence of the knitting industry in Baden-Württemberg; the MICROFACTORY, a fully networked, integrated production chain, from the design right up to the finished product; as well as the project Mittelstand 4.0-Kompetenzzentrum *Textil vernetzt* [mid-sized companies 4.0 center of excellence for networking in the textile industry], which explicitly supports small and medium-sized enterprises (SMEs) in the textile industry, textile machinery and related sectors in expanding their digital fitness.

ADD International Textile Conference – Launch in Stuttgart

Change always includes the acceptance of a new challenge. For the first time, DITF organized the Aachen-Dresden-Denkendorf International Textile Conference at the end of 2017, one of the most significant textile conferences in Europe. The successful launch at the Liederhalle in Stuttgart attracted more than 600 experts from 28 different countries and four continents. The Textile Conference was all about forward-thinking developments in textile technology and drastic changes. The conference program covered a wide range of topics, from additive manufacturing methods, such as textile 3D printing, to smart textiles and absorbable polymer implants, to high-performance fibers and their associated process technologies.

2017 – The year of trade shows

Our event calendar in 2017 boasted no fewer than nine trade fairs, including Techtextil, MEDICA, JEC World, as well as Index. The trade shows embody an ideal marketplace for us to make our developments and research results more widely known in an international context and, based on this, to gain new customers and establish

research partnerships. There were some novelties in this area as well: the DITF were present in the USA for the first time in many years and took part in the IFAI Expo in New Orleans. We used the expo for the enthusiastic promotion of Baden-Württemberg as a location for innovation and for the strengthening of our international connections.

Successful evaluation

At the end of May 2017, a high-ranking panel of experts evaluated the DITF together with all other institutes of the Innovation Alliance Baden-Württemberg. The comprehensive review serves to monitor the effectiveness of implemented measures as well as proactive management. Both are crucial and help us to improve our work further. The evaluators from industry, science, and the Ministry of Economics, Labor and Housing Baden-Württemberg were impressed by the range of services that is unparalleled in the global textile research landscape, not to mention the focus on applied research. In its final report, the commission particularly commended the close integration of research, teaching, and its application. The excellent result motivates us in return to continue on our successful path.

This annual report presents our scientific highlights from the key growth sectors of the country. We report on trend-setting developments from the molecule to the finished product and demonstrate the full range of applications as well as the enormous potential that fiber-based materials and textile technologies offer.

We thank our customers and partners for their trusting cooperation during the past year and look forward to future challenges and ongoing dialogue with you. This annual report shall provide you with an insight into the details of our research, as well as the ideas and innovations by the German Institutes for Textile and Fiber Research Denkendorf.

The DITF Board

Prof. Dr.-Ing.
Götz T. Gresser

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

Peter Steiger

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> Publicly funded research projects

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> Events, trade shows, exhibitions

> Patents

> Bodies, scientific advisory councils

Orders: info@ditf.de

DEUTSCHE INSTITUTE FÜR
TEXTIL+FASERFORSCHUNG

GERMAN INSTITUTES OF TEXTILE AND FIBER RESEARCH DENKENDORF

THREE RESEARCH FACILITIES. ONE BRAND.

Three research facilities are united under the umbrella of the DITF. These include the Institute of Textile Chemistry and Chemical Fibers, the Institute of Textile and Process Technology and the Center for Management Research. Each has its own research focus and its own expertise. Their potential lies in their close connection under the DITF umbrella brand. Together they form Europe's largest textile research institution and cover the entire production and value creation chain for fiber-based materials.

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 300 scientists and technical employees, the DITF cover the entire production and value creation chain in textiles as the only textile research institution in the world. We have been covering all the important textile topic fields since 1921. We count among the leading research institutions in our field of work worldwide.

Application-oriented research from molecules to products

We carry out application-specific research over the entire textile production chain. Our technology oriented innovations as well as modern management concepts 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

We 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. We 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

We 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) and a shared professorship. 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

We 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

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

Prototype construction

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

Please ask us!

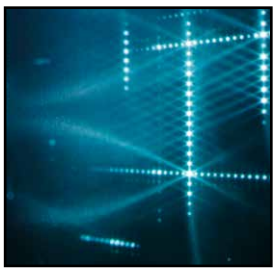
DITF RESEARCH FIELDS

The 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

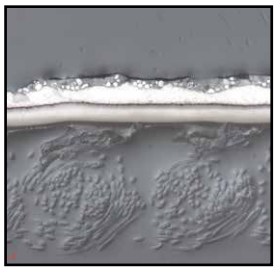
High-performance fibers and yarns

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



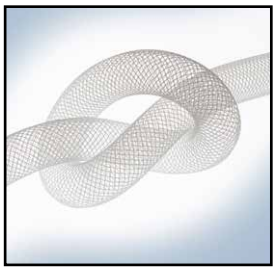
Smart textiles

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

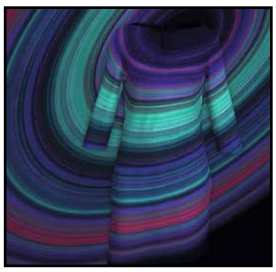


Medical technology

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

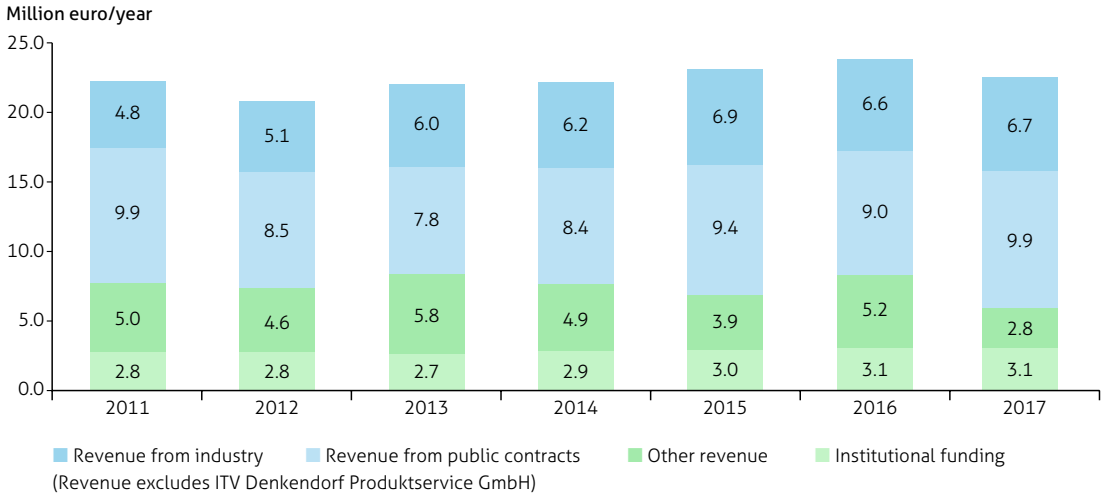
Fibers, structures and products e.g. for the automotive industry and for aviation and space travel technology

Clothing and home textiles

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

FIGURES – DATA – FACTS

DITF Revenue 2011–2017



Stable revenue performance

The total revenue from ordinary business activities amounted to 22.6 million Euros in 2017 and is, therefore, less than the results of the previous year. Fortunately, revenue from public contracts increased sharply, whereas income from industry increased slightly. Overall, however, this uptrend was not enough to offset the decline in other earnings.

Institutional funding by the Ministry of Economics, Labor and Housing Baden-Württemberg increased slightly in the past year and remained virtually unchanged from the prior year at 3.1 million Euros.

SMEs are particularly prominent in revenue from industry. They generated approximately 49 % of revenue from industry in 2017. The focus on SMEs is further highlighted by the large number of ZIM projects, which accounted for 25 % of revenue from public contracts during the period under review.

Employees as of 31.12.2017

DITF
239 employees
120 scientists and engineers
119 non-scientific employees
12 doctoral candidates
82 students
(undergraduates, graduates, degree candidates)

ITV Denkendorf Produktservice GmbH
54 employees

Quality management

Selected DITF and ITV Denkendorf Produktservice GmbH laboratories are accredited according to DIN EN ISO/IEC 17025:2005.

The area of Biomedical Engineering, PET yarn and PGA fleece, as well as the ITV Denkendorf Produktservice GmbH are certified according to DIN EN ISO 13485: 2012 in the field of design and development, production and sale of absorbable and non-absorbable surgical sutures, implants and wound dressing materials.

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 13 non-academic, business-related research institutes with a total of 1,150 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

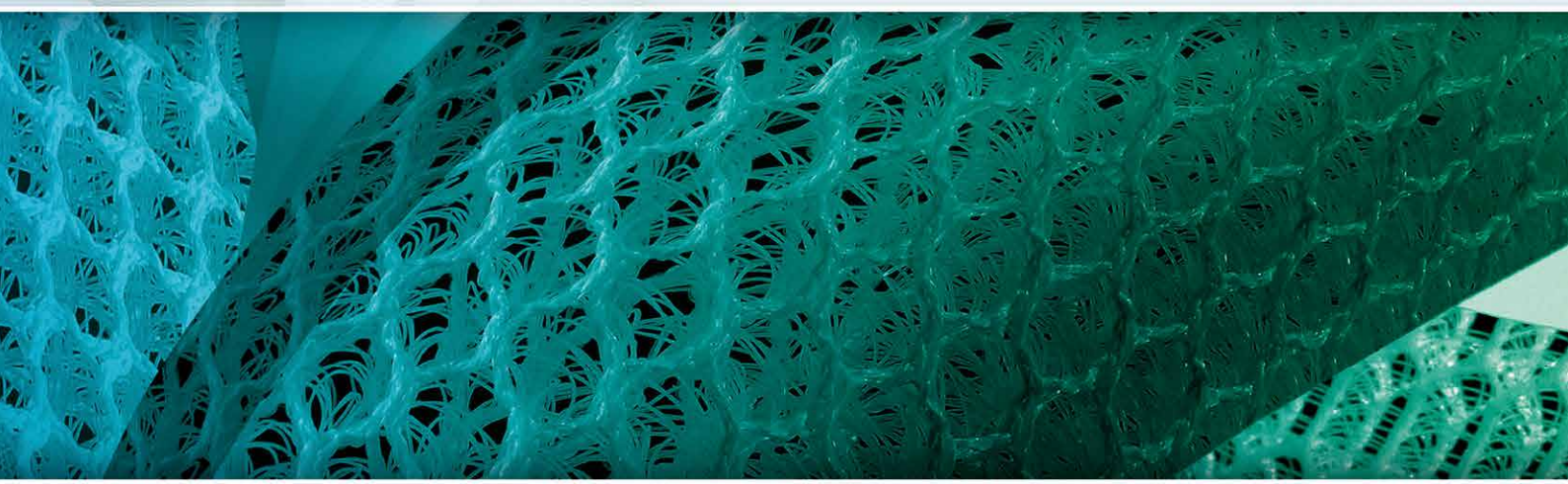
DITF co-founded the German Industrial Research Foundation Konrad Zuse e.V. This association represents the public interests of non-profit industrial research institutions in Germany and is open to all technologies and sectors. Its members include independent research institutions from all over Germany.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

Forschungskuratorium textil · AiF Mitglied · Textranet European Network of Textile Research Organizations · südwest textil · GESAMTMASCHE

Universität Stuttgart · Hochschule Reutlingen Reutlingen University · DIGI4TT Digitaldruck Technische Textilien · AFBW Allianz Faserbasierte Werkstoffe Baden-Württemberg e.V. · edana

BioRegio STERN · MedicalMountains · TechnologyMountains · microTEC Südwest · Allianz Industrie 4.0 Baden-Württemberg

ARENA2036 · LEICHTBAU BW Landesagentur für Leichtbau Baden-Württemberg · LBZ Leichtbauzentrum Baden-Württemberg LBZ-BW e.V. · CERAMIC COMPOSITES · High Performance Member Carbon Composites Mitglied · Kompetenznetz Biomimetik Competence Network Biomimetics



ARCHITECTURE AND CONSTRUCTION

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

- Textile facade elements
- Light-guiding textiles
- Smart textile construction elements
- Pneumatic textile actuators
- Autonomous living walls
- Textile moss walls for particulate reduction
- MucorPrevent: heating textile material to prevent mold
- Flectofin: smart, lightweight building shading
- Sonic textiles
- New membrane materials for textile construction

Architecture and construction

Highly innovative approaches are the hallmarks of the construction industry. We must address the challenges associated with the increasing scarcity of housing space and growing density of urban development, as well as the improvement of ambient air quality and optimization of resource use to fulfill statutory requirements. Metropolitan areas have an increasing need for solutions involving qualitative redensification of the available space. Such solutions should also help to develop commercial potential conducive to social redensification to create affordable housing.

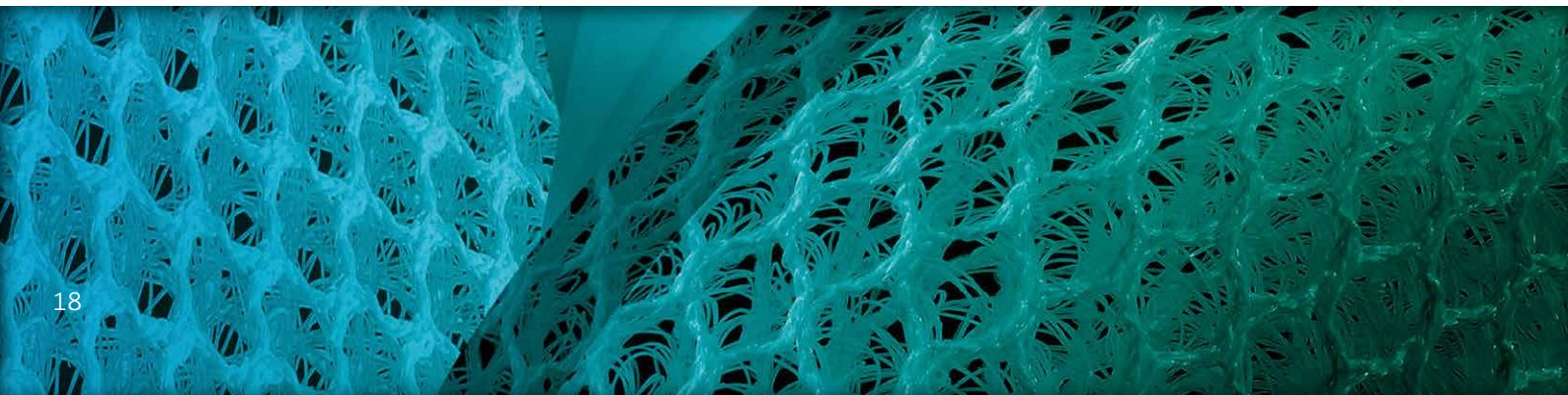
Functional, smart building textiles

Textile solutions for addressing these issues can be found, for example, in the development of new materials and structures that can be integrated into new products and components. Few components today fulfill only a single function. Accordingly, they will often 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. The DITF develop feasible and efficient solutions for this, which ideally address the issues of redensification.

Textile solutions for redensification

The Denkendorf research cube 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 measure the illuminance as well as control textile-based actuators that adjust the shading depending on the position of the sun. Such smart and active building textiles cannot only be used in the smart home but also present an ideal basis for the realization of so-called smart districts, where entire streets are interconnected in a smart network. The aim is to manage issues relating to energy production and consumption as well as water supply and wastewater disposal in increasingly paved areas across all districts.

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

The integration of sensors into fiber-reinforced composites within the context of the Collaborative Research Center (CRC) 1244, among other things, will generate a complex component that will detect deformations and a partial failure of building envelopes or concrete structures.

Aside from the identification of suitable fibers, along with the independent development of polymer-based resins, which are employed as cured thermosetting matrix composites, the selection of sensors is another crucial step. The sensor structures are printed on the fabric in a screen printing process using a conductive paste (e.g., carbon black, silver). The DITF have the relevant experience and knowledge needed to produce fibers (primary spinning) and the conductive pastes based on electrically conductive particles and binders. Of crucial importance for the production of sensors in fiber-reinforced composites is the expertise needed to treat (textile) supporting structures with sensor-active materials as well as the use of coating techniques such as inkjet and screen printing.

Following the sensor printing, these fiber-based sensors are to be fitted with electrical connectors and covalently embedded in a suitable polymeric matrix.

Research cube

The research cube at the DITF comprises a separate research area with about 40 square meters of floor space. It automatically records photometric parameters like the irradiance and the illuminance of incoming direct sunlight, as well as weather data throughout the year. Its six large windows and precise southern orientation make it ideal for reproducing and measuring different situations with daylight and artificial lighting.

Denkendorf research cube

Results for the industry

We use the cube to determine the structural characteristics of textile materials, which can then be made available to the industry and serve as the basis for their research and development work. We develop and test textile facade systems that, for example, protect against warming solar radiation, while at the same time not obscuring the user's view of the outside from inside. We rely on close collaboration with companies and other research institutions in this context. We have installed living walls on all four sides of the facades. These do not constitute an isolated test station but serve to be used and developed directly in an applied assembly and usage situation as an integrated component of the facade. The research cube is also used in the context of the project Mittelstand 4.0-Kompetenzzentrum *Textil vernetzt* to demonstrate the possibilities of digital networking between industrial and craft sectors to develop an individualized production.

Sensors in fiber-reinforced composites

As part of the CRC 1244, the DITF develop sensors embedded in fiber-reinforced composites and test them inside the component under mechanical stress conditions. After successful validation of the sensor system, they then plan the integration of the sensor composites into a ten-story high-rise building.

Use in facade elements

The project entails the development of both non-transparent and transparent sensors in fiber-reinforced composites. The non-transparent developments are intended for use in facade elements, as well as the coating of concrete girders. The preferred fiber material so far has been glass fiber fabric. The use of carbon fibers provides for better material properties of the composite; however, they are electrically conductive and must thus be provided with an electrically insulating layer, so that the connected current flows exclusively through the sensors. The polymeric matrix developed in-house is based on an anhydride cured epoxy resin.

The transparent sensors in fiber-reinforced composites are developed for use as facade elements such as windows. The decisive challenge consists in adapting the refractive indices of the polymeric matrix and the fabric to ensure optimum transparency of the material. In this context, fiber material based on transparent glass fibers is the only option. The resin, which envelops the glass fibers as a thermosetting polymeric matrix, was developed from a methacrylate system using chain-transfer reagents.

Cured transparent resin

Okalift SuperChange

Okalift SuperChange is an interchangeable fabric system for wall and floor coverings developed by Kiesel Bauchemie GmbH in collaboration with DITF. The two-layered fabric is glued between the wall or floor covering and the substrate, which allows it to be removed with considerably less effort and dust. Thus, renovation professionals can remove an area of 60 square meters in just one hour.

Okalift SuperChange

Construction as a two-layered fabric

At the same time, the system possesses uncoupling and crack-bridging properties. It is suitable for use with any wall or floor covering that is laid over an adhesive system, e.g., tiles or parquet. The Okalift SuperChange system consists of two textile layers, which are selectively interconnected by woven threads contained in the fabric. During the removal of the flooring, these become predetermined breaking points, so that the lower layer adheres to the substrate and the upper layer can be removed with the surface covering without leaving any residue. The lower layer remains attached to the substrate and can be processed further immediately.

Unlike most other interchangeable fabric systems available on the market, Okalift SuperChange does not require any special preparation of the substrate on which it is applied. Compared with the frequently used single-layer nonwovens, the double-layer construction of the fabric also has the above-described favorable properties.

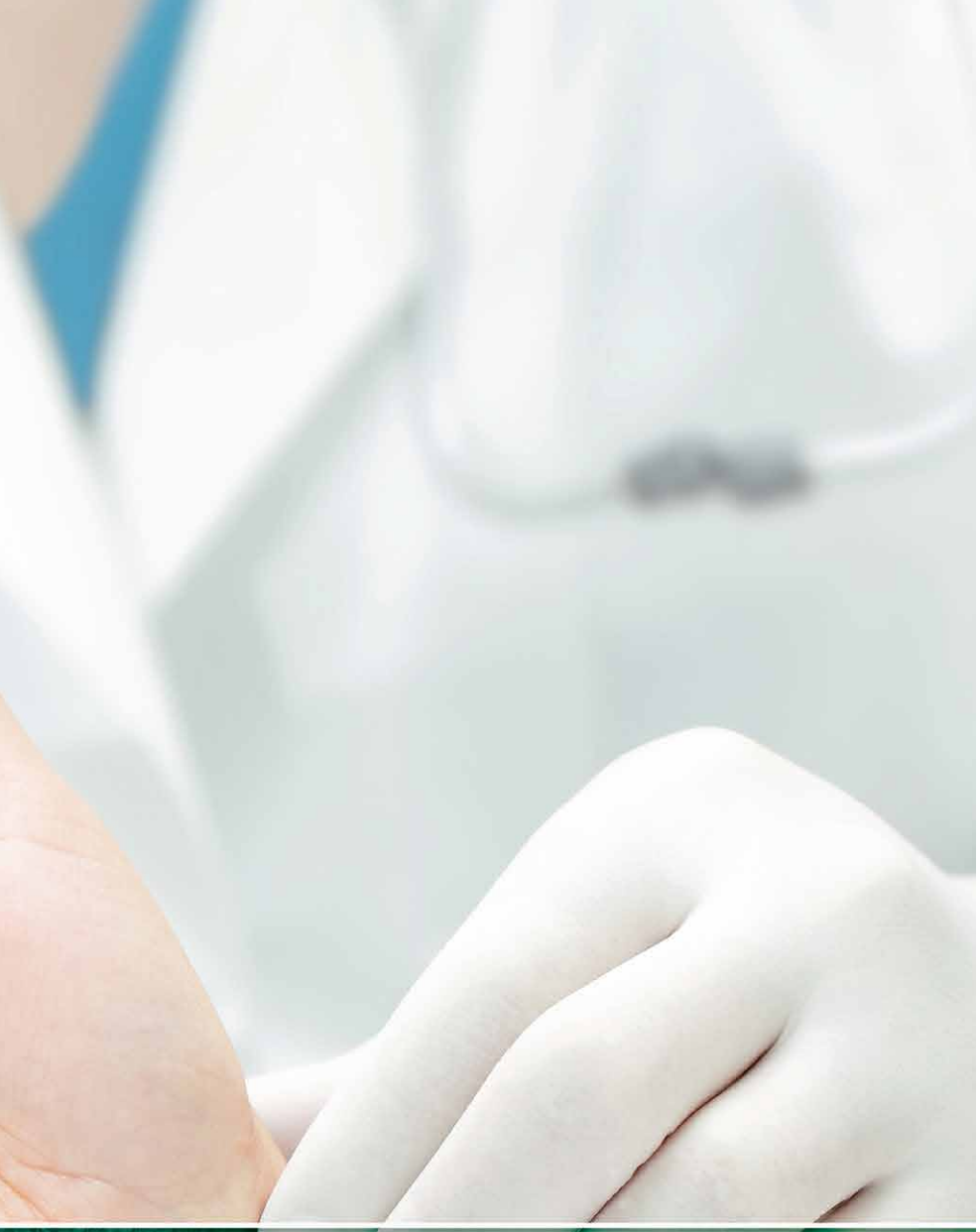
Living Wall

This field of research seeks to fit walls covered with greenery, so-called living walls, with textile supporting structures, integrated textile lighting and water supply and textile sensors, both indoors and outdoors, making them autonomous and easy to use. Employing a combination of tried and tested as well as new textile-based components improve not only the supporting system but also the water supply, the moisture sensors, as well as the overall appearance.

Ideal conditions for plant growth

Moreover, the objective of direct-integrated sources of lighting with textile lighting structures and light-sensitive threads is to ensure an adequate energy supply of the plants at the optimum wavelength, which has a positive effect on plant growth. This approach carries the significant advantage that the living wall no longer has to be set up in sunlit locations. The customer can freely choose a location and does not need to install additional spotlights. Another innovation of the planned approach is the replacement of the previous rudimentary control with a smart control system that includes a customized operating concept. The modular concept allows the customer to specify individual, time-variable target values per module, which increases the robustness of the entire system. Sensors report the actual growth-relevant parameters to a central control unit, which can subsequently supply water and lighting to counteract shortages. This structure ensures optimal growth conditions even in changing environmental conditions.

Experimental setup for the development of living walls



HEALTH AND CARE

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

- Resorbable polymers and bio-materials
- 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 coating systems
- 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

Health is our greatest asset; hence, we do not worry about saving money. This mindset makes this industry so exciting because it is incredibly resilient and continuously growing. Moreover, it offers an almost inexhaustible potential for research and development opportunities, because virtually all therapeutic procedures can be improved and many diseases still push medical knowledge and technical capacity to their limits. Modern medicine is expensive. Subsequently, this results in enormous pressures for the development of inexpensive, effective procedures.

New regulatory requirements

Medical technology is currently facing significant problems: In its efforts to ensure high standards of patient safety – and alarmed by the criminal behaviors of individual companies – the EU introduced a new medical device regulation for the entire sector in mid-2017. Not only does this regulation make the approval of new medical devices much more difficult, but it also results in additional bureaucratic demands for the day-to-day operation. Moreover, the ISO published an updated version of the standard 13485, which applies to medical device manufacturers. The implementation of these two regulatory requirements will overburden many companies, and the consequences are not yet foreseeable.

By contrast, the DITF are well situated in this field. We have been researching and developing fiber-based medical devices from polymers to implants or hospital textiles for more than 40 years. Certification according to ISO 13485 allows us to produce prototypes for use in humans in the cleanrooms of the institutes and their subsidiary, ITV Denkendorf Produktservice GmbH (ITVP). Finally, ITVP also makes its production facilities available on request.

DITF and ITVP have already successfully changed to the new ISO standard, and the adaptation to the EU regulation is currently underway. Thus, partners of DITF and ITVP, who collaborate with them on new products, not only benefit from the know-how and the experience of the institutes but also from conditions for research, development and production that meet all current legal requirements. The following pages offer examples focusing on fibers that the DITF develop and manufacture for medical purposes according to customer requirements.

New materials

Although it is becoming increasingly difficult to gain approval for new materials and devices for medical applications, discovering the potential of novel materials continues to be exciting. The team headed by Frank Hermanutz, Head of Biopolymers and Wet Spinning Technology, has taken an exciting step: They are intensively researching the numerous possibilities of the fascinating and versatile biomaterial chitin. Medicine and biotechnology use chitosan, which is manufactured from chitin in an elaborate process. Chitin, on the other hand, is more readily available, much cheaper, and would be equally versatile if it would not be so difficult to dissolve. The newly developed process for processing chitin opens many new possibilities, especially in medicine.

Individualized medicine

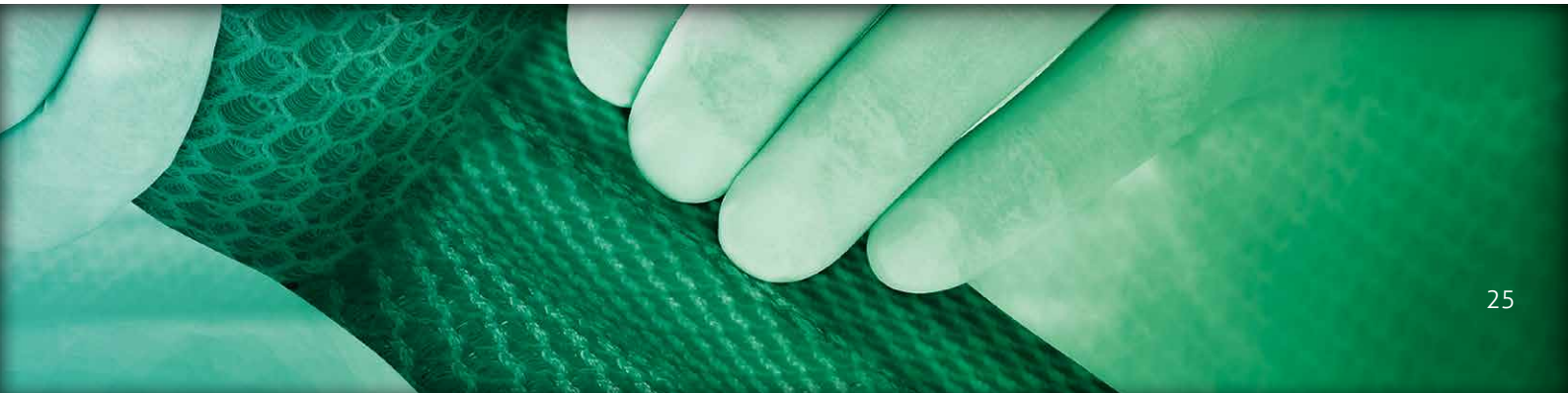
Digitization and individualization are also gaining importance in medicine. A recent project of the Federal Ministry of Education and Research, which is being coordinated by the DITF's Management Research division, tackles the continuing problem of scarring. Compression bandages with an individual fit and physiology are designed to optimize the wound healing process to prevent scar formation altogether.

Not only the established employees with longstanding experience but also young and dedicated talents, who are still completing their university education, are successfully working on the diverse research and development projects at the DITF. Students mainly come from the medical technology study course at the University of Stuttgart, but also from other universities with technical/natural science programs from all over Germany. Every year, Denkendorf welcomes many students for the completion of their coursework and final theses.

Innovative medical device development

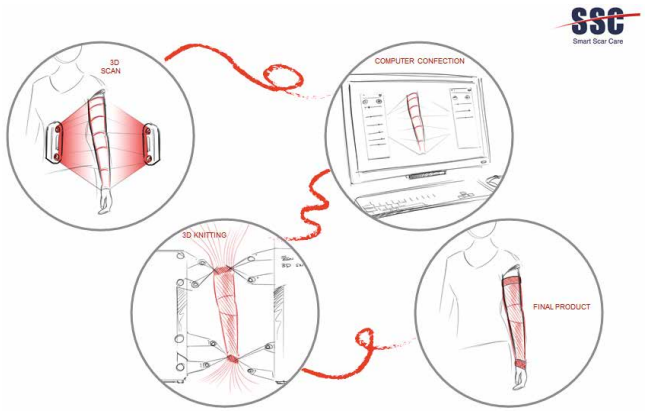
Katrin Malunat, a young researcher in the medical technology department, has developed a new procedure with colleagues in the fields of biomedicine and filament yarn technologies to produce continuous channels in bone substitute materials, allowing subsequent ingrowth of new blood vessels essential for regeneration. The procedure has since been patented.

Not only is medical technology at the DITF state of the art, and in line with regulatory requirements, the institutes also offer the entire spectrum of innovative medical device development from polymer development to biomaterial processing and functionalization to prototype production under certified conditions. This array also includes cell biological and microbiological tests for functional testing in vitro.



Smart scar care

"Individual patient data recorded at the bedside feed directly into industrial manufacturing", sums up the innovations of 3D-based treatment processes for the individualized care of burn patients. In this context, the individualized burn garments derived from the patients' 3D data considerably improve the care of burn patients and minimize scarring. Smart scar care aims to make burn garments marketable that can be manufactured industrially and customized in terms of fit, compression, pore structure and microclimate.



Make-to-order process for individualized burn garments following the concept of smart scar care

Make-to-order process

This concept requires an innovative make-to-order process, which consists of the following sub-processes: (1)recording of individual body measurements with 3D scanning technology, (2) configuration of the product via a treatment configurator, (3) 3D simulation for product evaluation and therapy control, (4) transmission of product data, (5) calculation of 3D flat knitting models using an interpreter, as well as (6) automated production of the customized burn garment. In contrast to the current care situation, this approach enables the contactless and interpolation-free recording of the patient's measurements as well as the production and provision of customized burn garments of a reproducible quality within 24 hours. The result renders an interim supply with wrap bandages unnecessary and improves the FIT rate.

Novel cellulose/chitin fibers with antibacterial properties

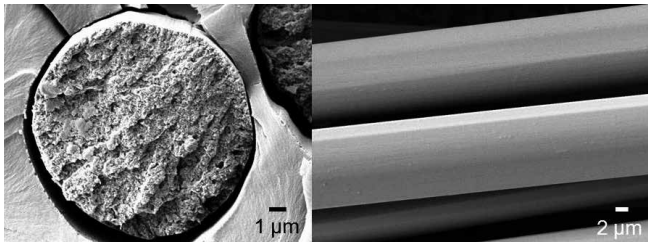
Cellulose and chitin are among the most commonly used biopolymers. While the methods for producing semisynthetic cellulose fibers have long been established, the industrial processing of chitin continues to be difficult.

One current research project used a mixture of cellulose and chitin to develop new, compact and microporous, highly absorbent semisynthetic fibers. The production of those fibers takes place through a process of direct dissolution in ionic liquids. The selected solvent is equally suitable for the processing of cellulose and chitin. For the first time, we can process these raw materials in a single process step. The result is the synthesis of an entirely new type of cellulose-chitin fiber blend.

Innovative potential for medical and hygiene applications

The fibers are biodegradable, biocompatible and have antibacterial properties. Nonwoven products developed from it are therefore likely suitable for a variety of medical and hygiene applications. One conceivable application could be wound dressings that accelerate the wound healing process.

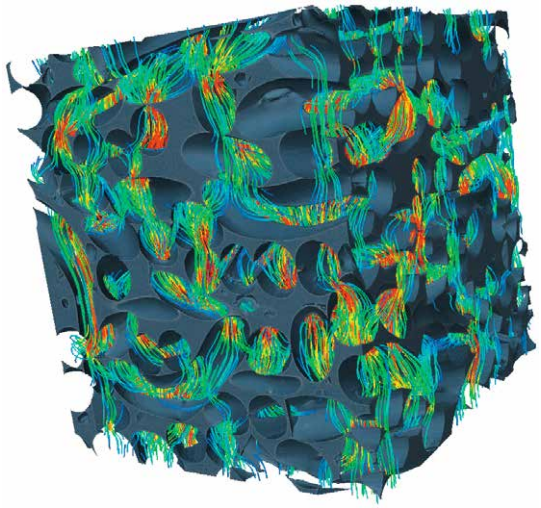
New fiber materials also entail specific chemical and textile-related physical properties. These attributes open up further opportunities for cellulose-chitin fiber blends, for example, optimizing the physical properties of technical papers or filter materials. The new production processes also benefit the environment: The production of fibers occurs in an environmentally friendly process that releases no pollutants.



SEM image of a chitin-cellulose semisynthetic fiber with 25 wt.% chitin

Bone substitute materials with interconnecting porosity

Bone grafting is still the standard treatment option for bone defects that are the result of accidents or tumor excision for instance. However, this approach has considerable drawbacks, such as a second surgical procedure for autografts or a theoretical risk of disease transmission for allografts. An alternative to bone grafting is the replacement of missing bones with bone substitute materials that accelerate healing and, ideally, resume the characteristics of the natural bone.



Flow simulation in scaffold with high porosity

Interconnectivity through dissolution of core component

We developed a scaffold with high porosity as a bone substitute material. This structure is composed of bicomponent short fibers with a water-soluble core. The sheath of the bicomponent fiber consists of a trimethylene carbonate and caprolactone-based block copolymer that has undergone functionalization with hydroxylapatite (HA). The sintering of the bicomponent short fibers followed by subsequent dissolution of the water-soluble core component results in an resorbable scaffold with high porosity and a continuous spatial connection of the pore system. The functionalization with HA significantly improves cell adhesion to the scaffold. Their nearly reversible degree of plasticity and flexibility in shape and size allows the manufactured scaffolds to be adjusted to the defect geometry easily. The use of microtomographic images and a flow simulation can reveal the interconnectivity of the pores.

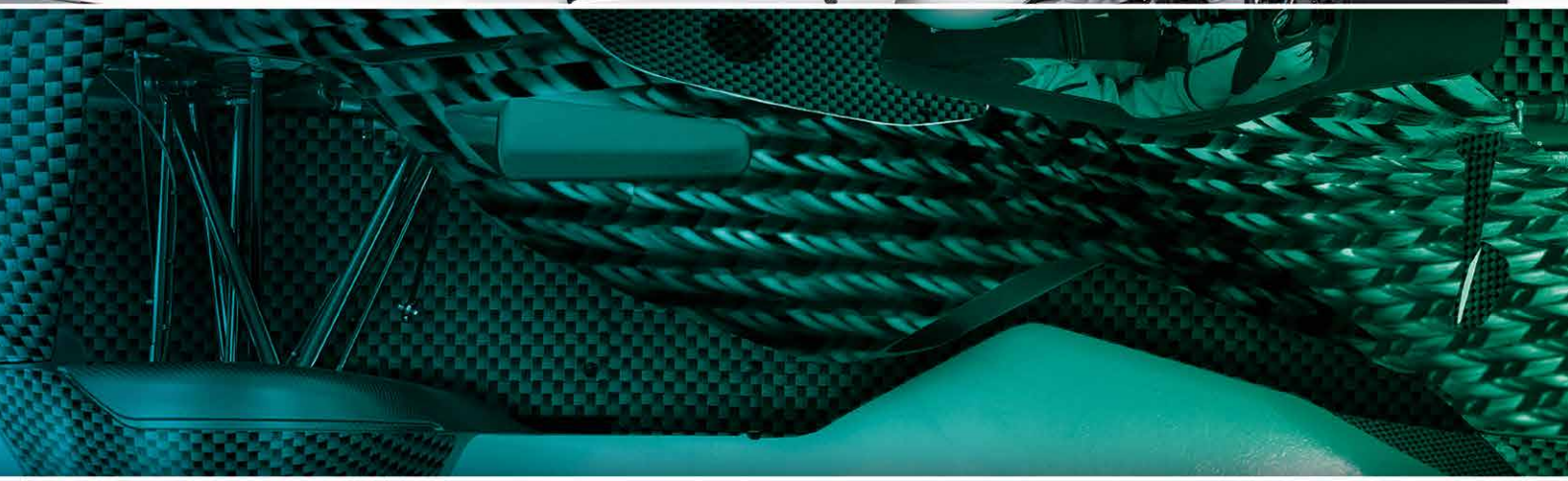
New filament yarns for implants

The DITF have been producing structures for textile-based implants for more than 40 years; since 2000, in their subsidiary ITVP. Production and development take place in a regulated area, certified according ISO 13485. We have customers from Baden-Württemberg (> 80 %), Germany (15 %), and worldwide (5 %). We source filament yarns and monofilaments from fiber manufacturers for the development of textile-based implants whenever they are available. However, the extremely high demands on quality, documentation and possibly cleanroom production, along with mostly small quantities (< 1 to./a), has increased the production of filament yarns and monofilaments at DITF. Accordingly, we have upgraded research spinning units to small-capacity production lines. Research in return will benefit from close-to-production developments, which is also in the interest of the technical textile industry.

Highest quality and production flexibility

At the institutes, we spin resorbable and non-resorbable filament yarns. The research division of DITF produces non-resorbable polyester yarns in the form of high-shrinking, high-strength or textured yarns, as well as highly orientated yarns (HOY). We owe gratitude to the company Trevira for their support in the establishment of this production. Furthermore, we produce textile and high-tenacity yarns by extruding and drawing resorbable polylactic acid. Strength characteristics of more than 60 cN/tex can compete with those of polyester yarns, thus making them also cutting-edge in the technical domain.

ITVP utilizes the cleanroom to produce mainly surgical suture material by spinning, drawing and further processing polyglycolic acid. Highly flexible, resorbable monofilaments made from a particular terpolymer developed in Denkendorf serve the same purpose.



MOBILITY

The world of mobility is undergoing drastic changes. Textile innovations by the DITF assist in shaping this process; while always keeping an eye on the current requirements for comfort, functionality, energy, and the environment.

- Fiber-based composites for light-weight construction
- Carbon fibers from renewable resources
- Technologies for carbon fiber recycling
- High-quality semi-finished products made from recycled carbon fibers for structural applications in automotive engineering and aircraft construction
- Ceramic Matrix Composites (CMC) for turbines in aircraft engines
- Load-converting textiles
- Economical and environmentally sustainable materials for fuel cells
- Cellulose-based filter materials
- Functionally integrated lightweight construction
- Further development of airbags and protective textiles
- Smart interior textiles for interaction with users
- Energetic concepts

Mobility

Fiber-reinforced composites have generally found their way into technology and everyday life. Their advantages include superior structural robustness and rigidity combined with low weight, high resistance to corrosion, as well as outstanding fatigue strength. Only the use of glass fibers has allowed wind turbine blades to withstand the high alternating loads. The increased use of carbon fiber has caused airplanes to become even lighter and use less fuel. While the excellent crash behavior of carbon fibers significantly mitigates serious injury in car racing, the rest of the auto industry have difficulty passing on the high manufacturing costs of the components to the consumers. What is required here is a well-thought-out hybrid (mixed) design with the right material at the right place.

Highly integrated (3D) textiles for automotive engineering and aircraft construction

BMW has incorporated carbon fiber-reinforced plastic (CFRP) into the roof rail of its new 7 Series by joining it to a steel jacket. The external metal part allows the structure to be connected to the car body by utilizing developed technologies while the internal CFRP tunnel ensures excellent crash performance in combination with an overall lightweight part. This component provides an excellent example of how textiles can contribute to the reduction of production costs, on top of short fiber reinforcements and tape layers. The use of new weaving, multiaxial and braiding techniques enables the production of highly integrated textile preforms that significantly reduce the otherwise relatively long time required to join individual fiber layers. These highly integrated (3D) textiles are currently being investigated for their application in aviation, as this sector could also benefit from reduced costs and processing risks.

Complex interaction of multiple components

The developments at DITF focus not only on textile reinforcement but also on different matrix systems. The aim is to achieve even better mechanical properties and much faster processing capabilities by further developing the interaction of up to 7 components in the resin systems. We employ so-called in situ polymerization systems for thermoplastic matrices, which will have a much broader application in the future. The caprolactam has an extremely low viscosity, wets the fibers very well and swiftly, and undergoes polymerization in the mold. These characteristics result in fast processes, low bubble formation and excellent recyclability of end-of-life components.

ARENA2036

DITF have been working closely with the OEM, computation companies and suppliers in the automotive sector for many years in the context of ARENA2036. The first four years of the joint project resulted in the development of a subfloor module equipped with a battery box,

which already integrates many additional functions in a single component; thus it is no longer necessary to add them in additional, expensive work steps. Close cooperation with the ARENA partners also led to significant further developments in the area of design and calculation of fiber-reinforced plastics. A fiber-reinforced composite with specific strength and rigidity requires the construction and determination of the fiber orientation. Therefore, nowadays an FRP constructor must be able to design and calculate simultaneously. The team at ARENA2036 develops the necessary tools, databases, and programs, aiming for user-friendliness and the lowest level of complexity.

Transfer to other industries and applications

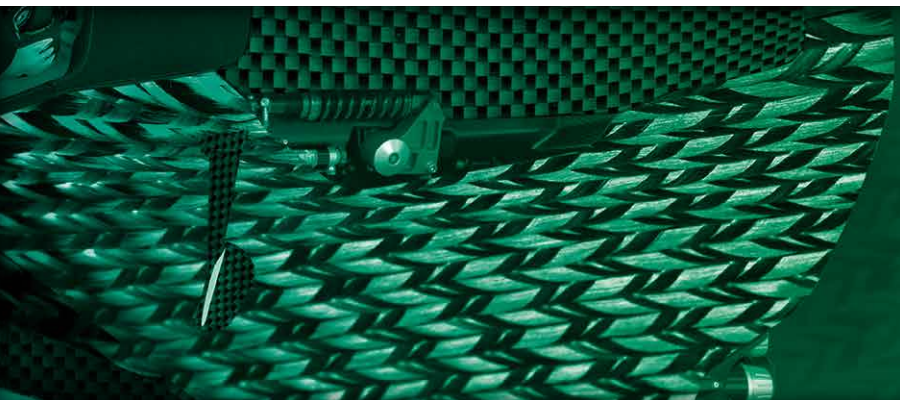
Research results in the area of mobility can also be used in the field of construction – and vice versa. DITF provide such transfer and cross-fertilization as part of the Collaborative Research Center Transregio TR141 "Construction and Bionics" by the German Research Foundation. As in mobility, the construction industry aims to reduce energy consumption in the production and operation of systems. Additionally, fiber-reinforced composites enable the creation of new delicate structures in forms that were hitherto impossible.

Future of fiber-reinforced composites

The characteristics of carbon fibers include high stiffness and low strain. Various DITF projects push lightweight construction to extremes, instead of laying carbon fibers flat in the form of textiles, they lay them individually along the force lines. This approach reduces the weight by an additional 10 - 20 %.

Finally, residual fibers, textile clippings, pre-pregs, and end-of-life components require large-scale recycling. The DITF are right at the forefront of development owing to their creating of systems and products that have received global recognition. If the recycling of fiber-reinforced composites becomes commercially feasible at competitive prices, then nothing stands in the way of their continued strong growth – including the corresponding environmental benefits.

Increasing the use of the favorable properties further and improving the environmental performance of fiber-reinforced composites require additional cross-cutting research and the participation of an interdisciplinary textile industry. The DITF are therefore closely involved with the Alliance for Fiber-Based Materials Baden-Württemberg (AFBW) as well as Carbon Composites e.V. (CCeV) and thus unite the expertise of various faculties in workshops and conferences.



New single- and double-component cast polyamide matrix systems in the lightweight construction of fiber made composites

Thermoplastic matrices are gaining in importance in composite manufacturing technologies because of their higher toughness (crash), faster processes and excellent recyclability. Winding and laying techniques work with less waste, balance the load path during fiber laying and can process tow-pregs and tapes with a thermoplastic matrix very well.

However, thermoplastics demonstrate a high melt viscosity even in their molten state; thus, their incorporation into densely packed textiles requires either high pressure or additional processing steps.

The in situ polymerization of polyamide constitutes a possibility for a complete and air-free impregnation of the fibers. This method uses pre-polymers with exceptionally low-viscosity (< 1 Pa*s), which quickly penetrate into the fiber composite and completely envelop the fibers – resulting by outstanding bond strengths. The tightly adjustable activation temperature causes the prepolymer to polymerize quickly to form the polyamide matrix.

Project Fast Matrix

The project Fast Matrix developed and characterized single- and bi-component polyamide matrix systems that could be polymerized in situ. A new latent single-component system that was developed at the DITF was compared with the bi-component in situ polyamide from Brüggemann. The project aimed to achieve a possible serial production of thermoplastic fiber composites while maintaining a consistently high quality of the components through the in situ process, i.e., simple, error-reduced production with decreased component rejection rates due to virtually unlimited pot life and a specified start of the reaction upon reaching the activation temperature.

In-situ polymerized demonstrator components manufactured through rotational molding

Project RecyComp: lightweight automotive components from recycled materials

Fiber-reinforced plastics (FRP) hold great potential for the design and construction of energy-efficient lightweight structures, which are increasingly gaining importance for many industrial sectors, in particular for the automotive industry. However uniquely this group of materials combines high structural robustness and rigidity with low weight, it is currently difficult to manufacture components in high volumes and return them to the material cycle following the completion of their life cycle.

rCF/PA wrapped hybrid yarn

Resource and energy-efficient production

The cooperation of an interdisciplinary research team from mechanical engineering, textile technology, aerospace and plastics engineering has enabled the creation and optimization of an entire process chain for the recycling of carbon fibers. The first step involved the load-balanced production of a hybrid yarn from recycled carbon and polyamide 6 fibers at the DITF, followed by the design and load-balanced manufacture of intermediate goods employing tailored fiber placement at the IFB Stuttgart, and finally the remodeling of preforms and production of parts using single-step injection molding compounding at the IKT Stuttgart. This collaboration successfully re-manufactured recycled carbon fibers into a component made 100 % from recyclate. Its mechanical properties closely resemble the characteristics of new carbon fibers.

The project has thus produced a component optimized for lightweight construction that represents a significant step toward sustainability in the use of carbon fiber-reinforced plastics.

ARENA2036 – Project smart lightweight automotive parts through functional integration

Since its inception, the DITF have been a partner of ARENA2036, the largest and leading research platform for mobility in Germany. The research factory specializes in reconceptualizing and implementing the entire value chain of the fully digital vehicle of the future. An important area of research is the project "LeiFu" – smart lightweight construction with functional integration – which benefits from the expert know-how at the DITF. Integrating functionality in lightweight construction allows the automotive industry to reduce the use of raw materials and energy as well as costs. The range of possible functions includes acoustic absorption, thermal, sensory or electrical features as well as liquid and energy storage. LeiFu examines the fundamentals of selected standalone features and demonstrates them on a specially designed floor module made from sandwich panels out of CFRP. The floor module reduces vehicle weight, comes equipped with a battery box and technologies to improve mechanical properties, as well as inductive charging coils.

Open Reed Weave (ORW) technology

Function-integrated CFRP rear end floor

The DITF contribute to the integration of structural functions by utilizing the Open Reed Weave (ORW) technology to develop components. Contrary to using standard fabric as an intermediate reinforcing textile, the ORW technology enables the single-step integration of additional fibers in 0°/90° fabrics during weaving, both surface-wide and locally; thus, allowing the combination of various fiber orientations. This approach creates the prerequisite for manufacturing intermediate textile goods that are well suited for the mechanical loads of components. Weaving trials demonstrate that the stitching of the additional reinforcing fibers and the main fibers is stable and secure.

Copper coil embroidered on structural textile

LeiFu charging coil

The integration of electrical functions within the context of "LeiFu" has led us to develop a charging coil for contactless induction charging. Commercially available charging systems generally have a minimum charging power of 3.3 kW and consist of several assembled and molded components. The construction of the LeiFu charging coil, on the other hand, relies on textile technology. The production of the copper coil requires embroidering individual strands on a high-strength embroidery fabric. Embroidery technology meets all the design requirements of a charging coil fixed on textile. Performing Vacuum Assisted Resin Transfer Molding (VARTM) turns the embroidered charging preform into the finished induction load module. The performed mechanical and electrical tests confirm that the damage-free production of a properly functioning "textile fixed coil" is possible. The measured electrical resistance values match the expected range for the correspondingly stretched length of the coil and the strand material used.

ENERGY, ENVIRONMENT AND RESOURCE EFFICIENCY

The DITF institutes develop processes 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.

- Coatings made from renewable resources
- Polymer synthesis with biogenic polyethylene
- Solvent-free, energy-saving processes for coatings and textile finishes
- Minimal application technologies
- Heat recirculation and heat recovery in dryer systems
- Novel textile or textile-based heat exchangers for recovering heat energy from sewers
- 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 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 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.

The development of processes 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. 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, 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 fuel cells, as well as new electrical energy storage systems. 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. 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. Such research entails working with the latest technology to process high-performance natural fibers into yarn, as well as new filter materials and composites made of cellulose and chitosan.

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.

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 process 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 as well as minimal application technologies such as foam application methods.

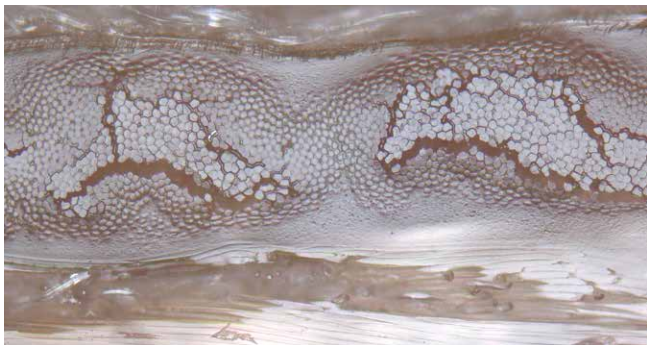
Additionally, we are exploring the further development of dryer systems with more efficient heat-material transitions, heat recirculation, and heat recovery, as well as smart process control systems. New ways of interconnecting equipment and coatings result in energy savings and superior characteristics. 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.

Biopolymers PURCELL and PULaCell

Researchers at the DITF have developed a substitute for non-recyclable glass fiber-reinforced plastics (GFRP), PURCELL – a new, mono-material and recyclable composite made from pure cellulose. PURCELL shall achieve a secure, stable, and affordable raw material supply for the GFRP-processing industry.

The single-component material demonstrates excellent fiber-matrix adhesion and is biodegradable. The exceptional fiber-matrix adhesion effectively transfers the forces exerted on the component from the matrix to the fiber. Recycled composites made from PURCELL retain their mechanical properties even in the fourth generation. The reshaping of materials made from Purcell only requires steaming with hot water, then they can be pressed into form again, thus enabling subsequent use.



Photomicrograph of Purcell; excellent fiber-matrix adhesion owing to a homogeneous composite

Purcell is easy to recycle since there is no need to separate fiber and matrix to obtain pure components. At Techtextil, the material received the "2017 Innovation Award" in the category "New Materials".

PULaCell

Another highlight in the field of sustainable material development is the PULaCell project. This is the name of a project that develops bio-based, cellulose fiber-reinforced plastic profiles for wooden structures. The researchers at the DITF accompany the entire development process right up to its use on an industrial scale with applied research. PULaCell exemplifies just how successful the replacement of petroleum-based polymeric matrices with renewable raw materials can be.

Fuel cells based on environmentally friendly and energy-saving resources

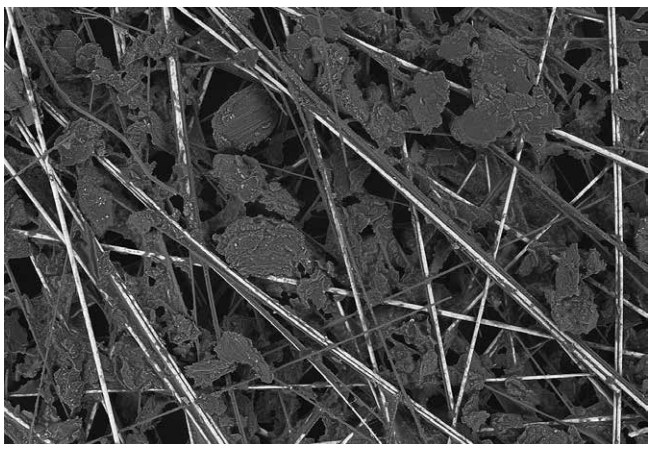
The energy transition has made energy storage and energy transformation the particular technical challenges of our time that require highly efficient, environmentally-friendly yet affordable systems. Fuel cells play a vital role in this context as they are highly effective and clean energy converters. The ecological advantage is that the conversion of oxygen and hydrogen produces electrical energy and the only reaction product is water.

The production of fuel cells currently relies on raw materials that pose problems for the environment: The gas diffusion layers (GDL) consist of electrically conductive carbon fibers, which are equipped with fluorocarbons to improve water repellency.

Use of eco-friendly raw materials

A collaborative research project of the Fraunhofer ISE and the DITF has led to the development of eco-friendly alternatives to the costly and polluting GDL structure made from carbon fibers and PTFE. The teams tested and developed electrically conductive glass fiber-based systems as substitutes for the energy-intensive carbon fibers. They replaced the environmentally problematic fluoropolymers with eco-friendly hydrophobic finishes.

The project demonstrated that it is possible to produce a fluorine-free, energy and cost-saving gas diffusion layer in line with the project idea with comparable functionalities.



SEM contrast image of the electrically conductive gas diffusion layer. Glass fiber nonwoven (light) with embedded carbon particles

Textile-based collector for solar thermal energy use

Solar installations extract environmentally friendly energy from solar radiation. Two types of solar installations exist: The photovoltaic system generates electricity, and the thermal solar plant creates heat. Thermal solar plants, in particular, have to store the extracted energy externally. The user faces massive structural installation challenges

Knitted latent heat storage

Integration of latent heat storage

A research project by the DITF lead to the development of a flexible, textile-made solar collector with integrated latent heat storage. Solar collector and heat storage are combined into one unit. A black absorber layer converts incident solar radiation into heat. The heat is transferred via air that is circulated through spacer fabrics. At the bottom, or end, of the collector, is the warm energy storage medium, this design permits direct storage of the sun-heated air. Storing energy utilizes enmeshed latent heat storage monofilaments made from Phase Change Material (PCM), it can save unusually high amounts of heat energy. The energy thus generated can be extracted on demand.

The solar collectors made from textile with integrated heat energy storage have the potential to be used in niche markets – its use as insulation makes them useful for applications in roofs and facades. Also possible is the application in mobile but also in the lightweight construction of novel building energy management systems.

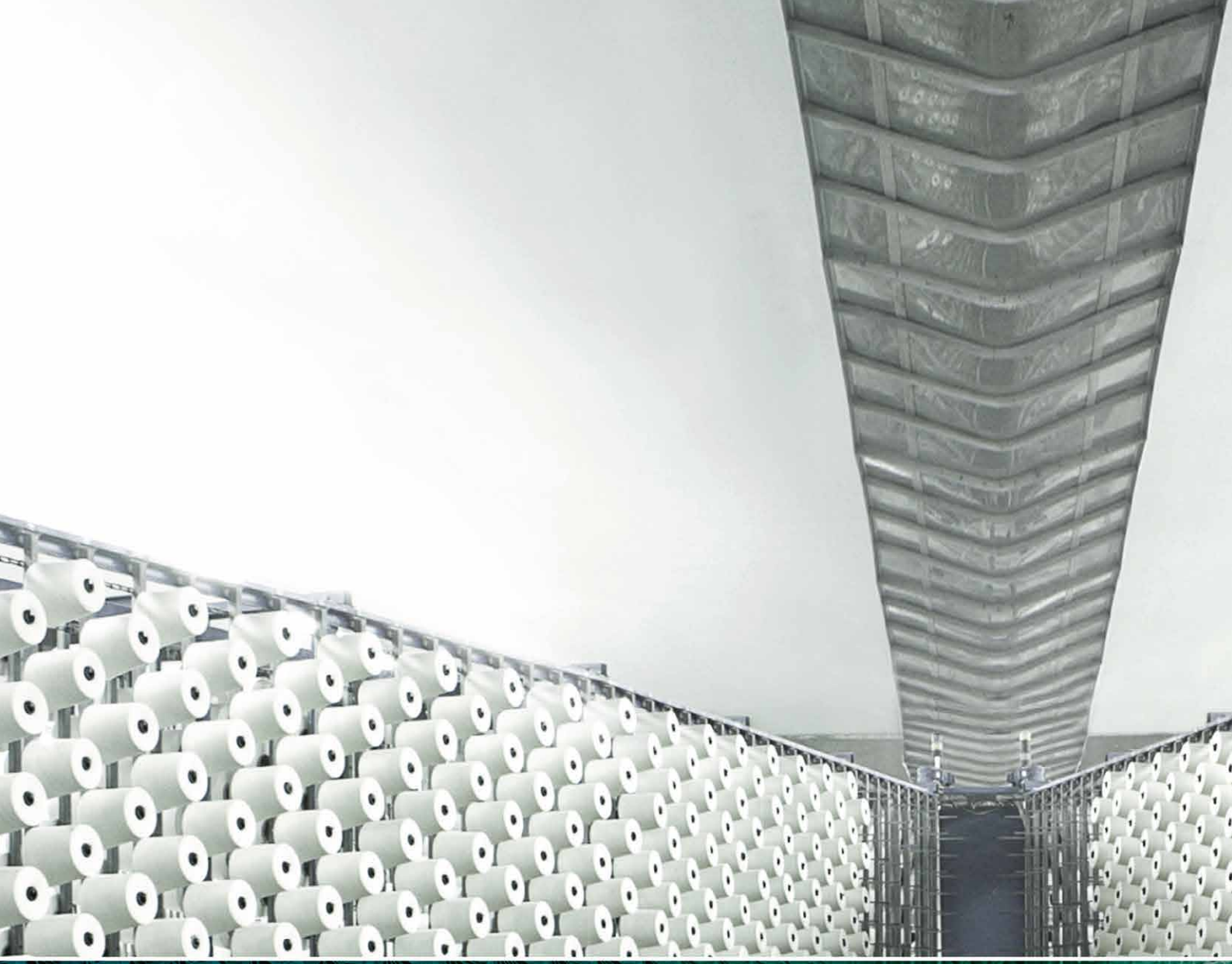
Energy independent irrigation systems

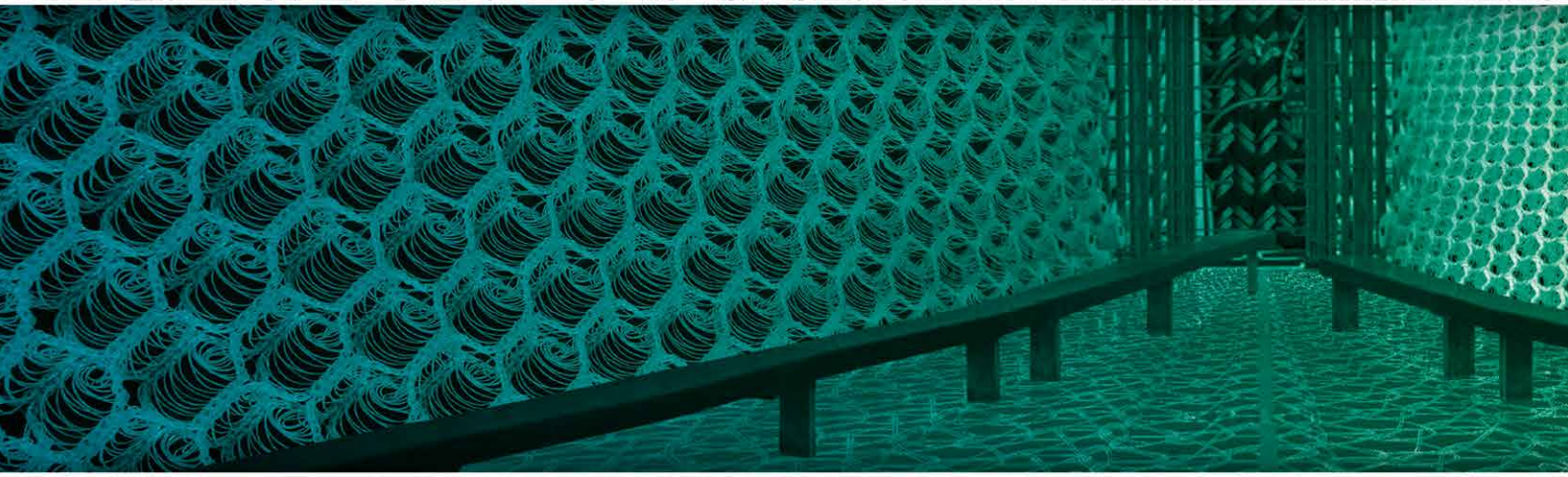
Increasingly, irrigation within greenhouses and outdoor vegetable cultivations is caught in a conflict between environmental consciousness and plant production. The demand for irrigation systems to save water and prevent the leaching of nutrients is in direct contrast with the need for plant and vegetable production to meet quality standards and produce increased yields. Irrigation systems have reached a high standard, but control and regulation pose a particular challenge. A more needs-based irrigation is relying on an increasing amount of sensors and control technology. It automatically leads to increased costs and higher maintenance.

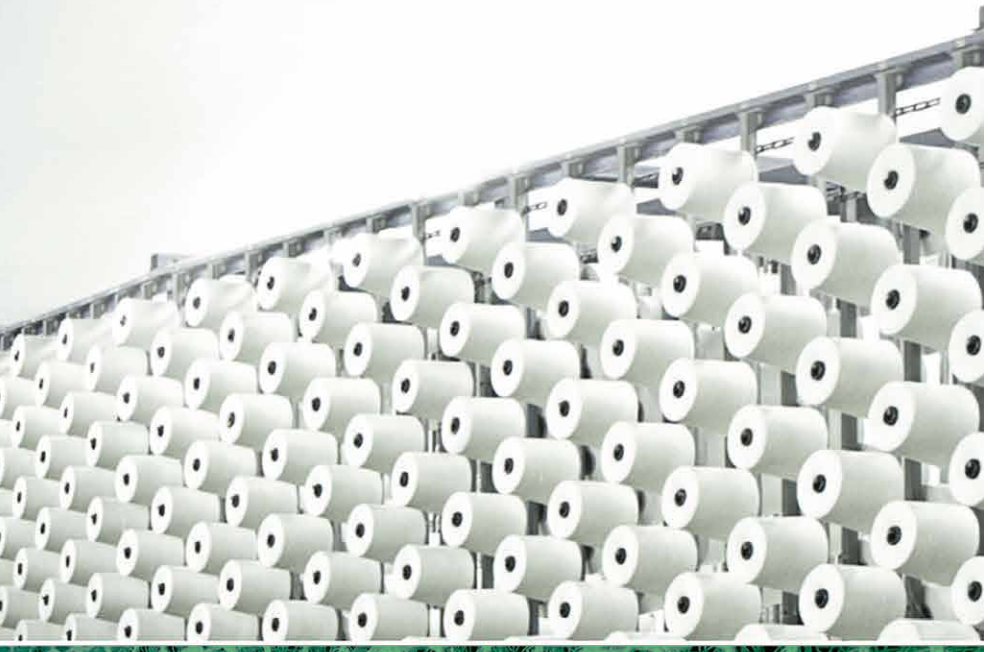
Use of capillary wicks

The DITF, in collaboration with the wick manufacturer WeDo and the Weihenstephan-Triesdorf University of Applied Sciences, developed an innovative irrigation system that works mostly without sensors or control technology and can be operated resource efficiently. The new system utilizes the intensely developed capillary forces of innovative textile structures from sheathed fiber bundles (wicks, twisted yarns, or nonwovens) for needs-based irrigation. The water supply is done via, so-called, seepage irrigation, straight to the plant's root area. When combined with customized water storage and transport, this permits efficient use of resources and at the same time prevents hyperhydration.

Testing of energy self-sufficient irrigation







PRODUCTION TECHNOLOGIES

The increase of innovative processes to ensure international competitiveness – new and improved technologies for the entire textile value chain.

- Smart process control systems
- Digital technologies for Industrie 4.0
- Functionalization of textiles with the help of robots
- Systems to bridge human-machine interaction
- Modeling and simulation technologies for textile industry processes
- Pneumatic textiles for factory automation
- Sensors and actuators printed on textile
- Efficient heat transfers in dryer systems

Production technologies

"Modern production technologies are essential for the industry. They are the driver for a 'smart production' and therefore a core factor for the competitiveness of industrial production". Thus describes the German Federal Ministry for Economic Affairs and Energy the importance of production technologies. German textile machine engineering, as well as the textile industry as a whole, have recognized the competition with Asia early on. Together, the industry has developed new process technologies for existing but also new applications, which, in turn, have increased competitiveness. Their success proves them right. Nowadays, textile machine engineering is a high-tech industry. Worldwide, every fourth textile machine comes from Germany. The German textile industry is highly specialized and leads Europe in the advancement of technical textiles. For nearly a century, the DITF institutes have been the leading partner of textile machine engineering as well as of the textile industry and have become the largest textile research center in Europe. Roughly a third of DITF research projects encompass production technologies, which make up the most substantial portion of applied research.

All stages of the textile value chain

Developing new process technologies in isolation is impossible. The development of yarn always comes with questions like how it behaves in its processed state, during finishing, or as the final product. The yarn will only prevail in the market by offering a different final product.

The DITF perform research at all stages of the value chain. They utilize the know-how of experienced specialists for individual processes; this results in the best possible solution for the customer. The foreground is always the holistic approach to research and development: all aspects, for example, technical, textile technological, and economic are considered. It is why the DITF experts come from different disciplines, such as textile technology, machine engineering, process technology, chemistry, physics, biology, cybernetics, computer science, and economics.

In keeping pace with industry-related processes

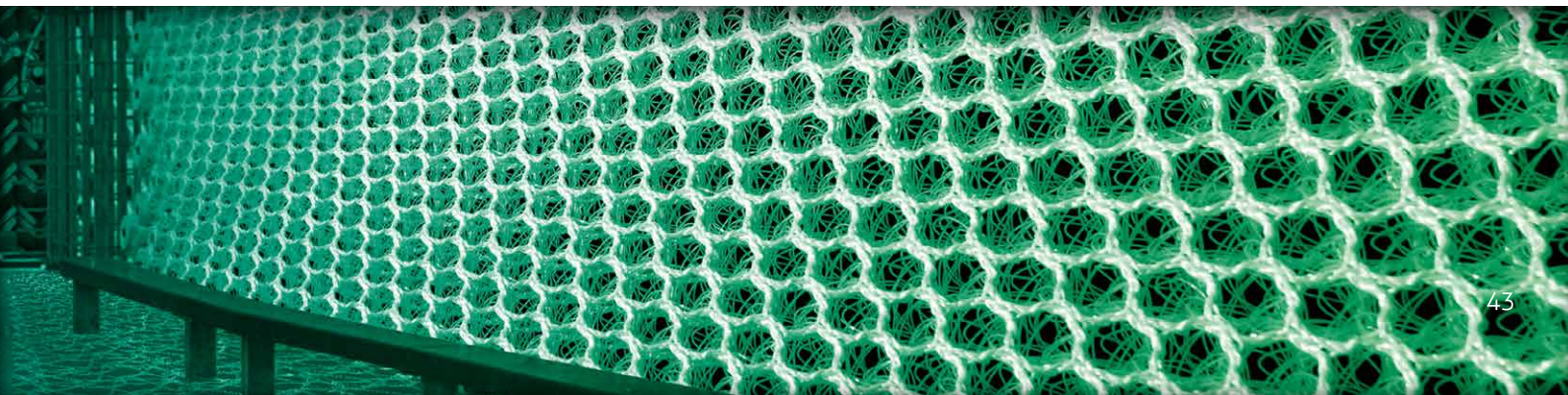
Applied research and development are only possible for processes that are close to the industry. The DITF have a research and production space of around 25,000 m^2, which permits a swift response to new production technologies and customer needs. We were able to equip industry machines with technology that has allowed us to conduct applied research and development in the areas of lightweight construction, complex 3D structures, digitizing, or the recycling of high-performance fibers. We can also cater for pilot or small productions. We develop and build prototypes in-house. 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?

Broad research in the areas of process technology allows the early identification and promotion of trends and challenges.

Textile machines of the future are multifunctional, easy to operate, and connected. The flexibility of machines becomes more critical to increase production. Machines with flexible batch sizes require flexible approaches that can be adjusted swiftly and therefore permit a more significant application. For this, machine concepts based on individual drives are required. Modern machine parts are multifunctional, light, exchangeable, and reduce costs of production and maintenance. Sensors monitor the quality online and can intervene as well as correct if necessary. Smaller batch sizes will also lead to automation since personnel is unable to deal with the increased logistical complexity.

Industrie 4.0 has arrived in the textile economy. Each step within the process chain will be automated. Tailor-made mechatronic settings and automatic systems facilitate the process monitoring and control, which, in turn, improves manufacturing quality and reduces costs. It is beneficial for technical textiles, in particular, since production batches tend to be smaller and processes shorter. Technical textiles will continue to gain in significance and increase their market share.



Automated end processing in robotic braiding

Robotic braiding permits the efficient manufacturing of complex shapes and close to the final contour preforms. Even though the robot leads the braided core, there are still numerous manual steps, in particular, the fixing of the pleating or cutting of the finished preform. The removal of the preform will be automated to improve occupational safety, reduce production time, and maintain continuous quality.

The removal of the braid roving and the created product require fixation of the braid. For this, the thread tension and yarn must be maintained and the braid fixed on the core. Cutting the braid must be done automatically and cleanly to prevent additional processing of the cutting edge.

Increase of automation

The DITF have developed and built two clamping devices to maintain yarn tension. The clamping fixture is activated once the braiding process is finished; this permits to decouple the robot and to start a new braiding core. First measurements have shown that the fixation remains stable for more than 24 hours. The developed cutting system is made from an electric rotary cutter that is mounted to a ring guide and moved around the braided core. This process permits clean cuts of various fiber types. The cutting of an additional layer of self-adhesive fiber grid is also possible.

Braiding machine equipped with clamping and cutting devices

Strick 4.0 study

Baden-Württemberg is the internationally leading location for the knitting industry. Innovative and successful suppliers, vendors, as well as end users, cover the entire value chain from textile machinery to the production of high-end fashion products. Together with DITF Denkendorf, they make up the most critical cluster of excellence in Baden-Württemberg. The DITF have compiled the status report "Strick 4.0" for this cluster of primarily mid-sized companies on behalf of the German Ministry of Economics, Labor and Housing Baden-Württemberg, as well as the Industrial and Employers' Confederation Südwesttextil.

Strick 4.0 study

Digital textile – the future of textile production

The study was conducted by the DITF management research division and formulated requirements toward companies concerning successful digitization but also sketched out the future of textile production. The study offers an analysis of the baseline situation concerning digitization and Industrie 4.0 for the Strick-Cluster Baden-Württemberg, but also shows the cluster's potentials and advantages when it comes to tackling Industrie 4.0 challenges. What innovations exist? Where are the possible areas of activity?

Specific examples from the knitting industry illustrate the digital revolution opportunities for the entire textile industry. A particular focus is on best-practice examples and the description of new business models for the knitting industry. It also looks at potential obstacles to the digital concept realization.

Mittelstand 4.0 Kompetenzzentrum *Textil vernetzt*

The Mittelstand 4.0-Kompetenzzentrum *Textil vernetzt* launched on November 1, 2017. DITF are project partners that work with a focus on "consistent digital engineering from design to the finished product" in the areas of apparel, smart textiles, and lightweight construction.

The German Federal Ministry for Economic Affairs and Energy has launched the "Mittelstand 4.0 Center of excellence – Digital production and work processes" within the context of the "Digitale Agenda 2014 - 2017". It serves to support small and medium-sized companies, and handicraft businesses in particular, to receive support when undergoing digital transitions.

A central feature of this initiative is the Mittelstand 4.0 center of excellence. It provides on-site support for small businesses and production facilities alike and offers its expert knowledge, demonstration centers, as well as network opportunities to experience practical examples but also to exchange knowledge.

The project has an intended running time of three years and is led by the Confederation of the German Textile and Fashion Industry.

Project focus

The Mittelstand 4.0-Kompetenzzentrum *Textil vernetzt* supports specialized small and medium-sized companies with smaller batch size and continually varying production nature to expand their "Digital fitness". The center of excellence focuses on new technologies in the areas of technical textiles and materials. The Kompetenzzentrum *Textil vernetzt* consists of four regional showcases, each with a different focus, as well as a showroom in Berlin, which provides a compact presentation of the lineup. The DITF institutes explore the following topics and projects in the areas of apparel, smart textiles, and lightweight construction:

Apparel

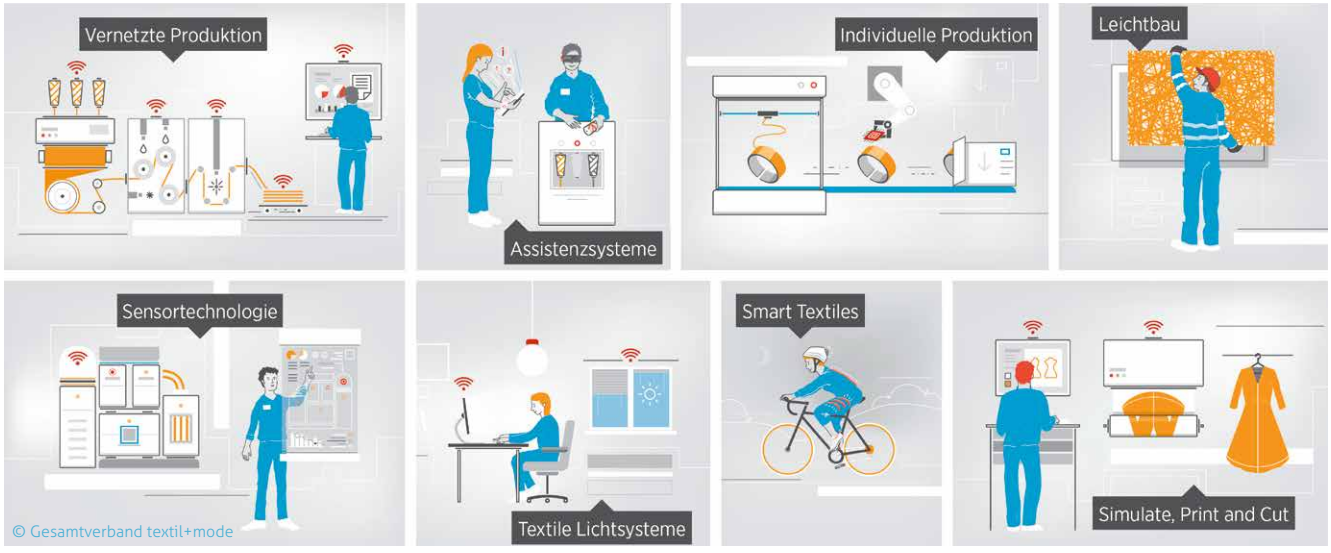
> Manufacturing of individual garments covering several steps in the production chain.
> Demonstration of a fully networked and integrated production chain – covering 3D design, large format textile printing, digital customization, and many others.

Smart textiles

> Automated and networked production of textile conductor tracks with non-textile sensors or actuator technology.
> Demonstration of a fully networked PLC-controlled production line for the bonding of SMD parts.

Lightweight construction

> Development of lightweight textiles that permit angle-sensitive and light-directing lighting functions.
> Demonstration of a research cube to scatter light for the best light distribution in a room.



CLOTHING AND HOME TEXTILES

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

> New fibers and technologies to improve mechanical, haptic, optical, or acoustic properties

> Bio-based fibers, additives, and (fluorine-free) finishing procedures

> Thermal radiation selective textiles

> Infrared reflective textiles

> Finishes for UV protection and improved fastness

> Compressive sports textiles

> Vasomotor adaptive functional underwear

> Energy-efficient functional textiles

> Personal protective equipment (flame or vector protection)

> 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

New ways of creating value

The current developments in the area of digitization and information technology permit traditionally oriented apparel and home textiles companies, in particular, to restructure themselves as well as their partner structures. New forms of value creation, mainly supported through digital services, facilitate connected and regional units for design as well as production in small quantities that have better chances of facing the current trend of individualization and therefore remain competitive. The DITF can demonstrate the newest digitally connected technology for development and production processes and additionally integrate them into tailor-made business solutions.

Data and knowledge-based services in networks for development and production

We also work with European partners to create technologies that allow a systematic integration of customer needs into the value creation at all stages of the supply chain. For this, sales data as well as also customer needs and preferences can be used to generate data-based services. It opens up new business models for service providers and customers alike. Big data – the analysis of vast amounts of data to generate knowledge – in combination with interactive and virtual product design environments, customization of apparel, demonstration of material functions, wearability, and lifestyle simulation can help make product development flexible, while sensibly limiting the complexity of related production processes.

Sustainability and new materials

Sustainability is also of increasing importance in the area of apparel and home textiles. The DITF show how essential the differences between traditional and sustainable systems are, for example, energy and resource efficiency. At the same time, we research the creation and application of materials obtained from renewable resources as well as the processing of high-performance natural fibers and yarns to create cellulose composites. We can perform life-cycle analyses to establish the amount of natural resources required and quantify the sustainability as well as the costs for existing and new materials alike.

Our expertise makes us part of European initiatives. We collaborate with companies from the textile, innovation, service provider, and business consulting industries to create broad ecosystems and find alternatives concerning excess production and depreciation. We also want to bring production capacities back to Europe; this allows the textile and apparel production to reduce their ecological footprint significantly.

Technological literacy and workplace learning

Changing working environments introduce an increased requirement for new and continually updated expertise. Technical assistance can support employees with amalgamated as well as easy to understand information and help production become more flexible and robust. It is achieved by combining data from machines and processes with staff knowledge.

This way, assistance systems can support employees with relevant information at the right time, place, and task. Fields of application include, for example, the new or low-skilled worker. Assistance systems can also support skilled employees to provide help and instructions to make the correct decisions in new and complex systems.

It includes applications like augmented or virtual reality, which are currently developed and tested for various domains.

The use of new technologies, materials, and concepts ensure continuous competitiveness

The global competition forces nearly all sectors of the textile industry to seize new opportunities based on technological progress to prevent a decline in value creation and strengthen competitiveness. Germany and Europe offer chances to concentrate on a greater diversity of individualized products with increased value creation to provide an alternative to the low-cost and mass-production approaches.

The creation of products that are of high-quality, technically innovative, and sustainable can only be accomplished by combining new technologies, materials, value creation methods, as well as skilled employees.

Our know-how covers the entire value creation process, from the molecule to the final product; we help your company to focus on needs-based, innovative, and individualized solutions.

Retail 4.0 – Virtual feedback for retail, and augmented shopping

The fashion industry is undergoing a structural change – multi-channel shopping is booming, collection cycles are becoming shorter, and the demand for individualized products is increasing. New digital 3D point-of-sale solutions are required to integrate retail and customers into the manufacturer's development process directly.

VR glasses for virtual shopping experiences

Current processes are dominated by traditional value-added structures that are based on separating development and distribution. The customer is not involved in design and development; customer feedback is reduced to sales figures. Targeted development and reliable demand estimation are challenging based on these variables – the results are shortages and overproduction.

The future of the fashion industry is digital and integrated. Digital technologies offer new opportunities. Apps and collaborative augmented or virtual reality solutions provide for the integration of virtual product development as well as the involvement of customers in retail. For this, consistent, flexible, and modular solutions are needed, which applies to retail in particular. The research project Retail 4.0 develops mobile device compatible 3D simulations as well as cloud-based VR solutions to achieve this goal. Innovative processes for the communication between retailer and manufacturer are designed and implemented for this.

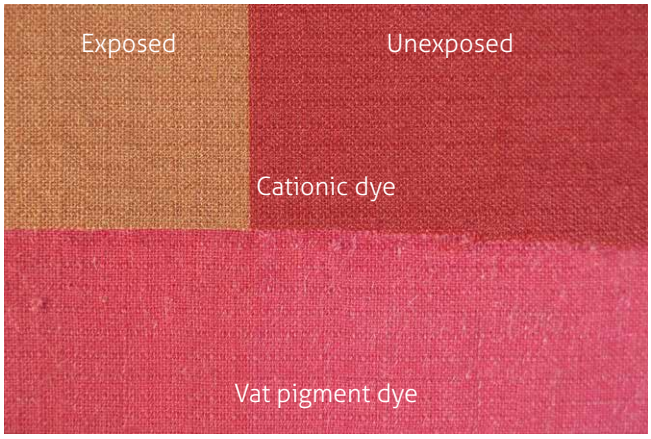
The coloring of meta-aramid textiles

Meta-aramid fibers tend to be colored inside the textile pulp; this is accompanied by familiar spin dying issues. Only a small percentage of the available meta-aramid is colored at a later stage; cationic dyes are used in an extraction process that relies on a carrier, for example, benzyl alcohol, which requires temperatures of around 115 °C. Poor lightfastness of the colored textiles are the disadvantages of this procedure.

Vat dye for new coloring methods

A research project workgroup in the area of textile chemistry is currently working to establish new coloring methods based on vat dye; this allows the creation of colorfast textiles made from meta-aramid only or a mixture from meta-aramid and FR viscose. For this, numerous vat dyes variants are tested for their color yield, fastness, and practicability. Notably favorable results are achieved through vat pigment dyeing. It can be done either continuously as a Thermosol process or intermittently in garment dyeing; both are established finishing procedures.

Camouflage apparel is an exciting application for the new coloration procedure. It also serves as an alternative to creating gray color shades, which is not achievable via traditional pigmentation coloration.



Effect of light – comparison of cationic and vat pigment dye

Outdoor clothing without fluorine balance pollutants

Functional textiles are water and dirt-repellent as well as breathable. These properties are made possible thanks to a microporous membrane made from polytetrafluoroethylene (PTFE). However, individual steps during its fabrication have proved to be harmful to the environment; it is also expensive to process. Thus, an increasing number of outdoor and workwear manufacturers are searching for new materials. The DITF, together with research partners and companies, develop at all stages of the textile value chain to find a polypropylene (PP) based alternative.

The institutes research a fluorine-free membrane for outdoor clothing

PP membranes are promising candidates for sustainable as well as environmentally friendly alternatives for functional, work, and protective clothing. Their advantages over PTFE membranes are their low environmental impact during production, processing, and waste management. Their lower production costs also provide the benefit of saving money. Polypropylene is the second most used standard plastic and is often used for packaging.

Researchers within the interdisciplinary research project gathered fundamental knowledge first and continued with processing principles of mating microporous PP membranes as breathable, water-repellent barriers in textile composites. The functional testing for operational fitness, environmental accounting, and cost analyses pave the way for later applications in the sector of functional, work, and protective clothing.

Measuring instrument concerning thermal transfer

Apparel textiles have parameters defining the transfer of heat and humidity concerning thermophysiological requirements. Depending on the qualification profile, these have unique and standardized set-properties.

Researchers at the DITF have developed a tool that measures thermal balance (WMB). It takes a series of measures to establish the heat transfer or interconnected transfer of heat and humidity in apparel textiles. For this, it simulates the transfer of heat and humidity in humans.

The thermophysiological properties of heat and humidity transfer in humans are always interconnected; this applies to various physical activities as well as environmental factors. Skin temperature, evaporation rates or electric heat output can be regulated variably and maintained if necessary.

The allocated construction elements like the baseplate, protection ring, and measurement zone, have integrated heating mats with individual PID controllers. The baseplate controller and protection ring are regulated by four temperature sensors inside the measuring surface, i.e., artificial skin. The development of two different measuring surfaces based on metallic and woven technology is a unique selling point of the WMB. Both measuring surfaces simulate key features of the human skin via a defined pore structure.

Thermal balance measurement setup (WMB)

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-Wuerttemberg 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-Wuerttemberg. 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, 36 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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The association is open to new members!
Join us!

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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Deutsche Institute für Textil- und Faserforschung Denkendorf

Koerschtalstrasse 26 | 73770 Denkendorf
Telephone: +49 (0)7 11 / 93 40-0 | Fax: +49 (0)7 11 / 93 40-297
www.ditf.de | info@ditf.de

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Deutsche Institute für
Textil- und Faserforschung
Denkendorf
Koerschtalstrasse 26
73770 Denkendorf
Telephone: +49 (0) 711 9340-0
www.ditf.de