DITF

DEUTSCHE INSTITUTE FÜR
TEXTIL+FASERFORSCHUNG

ANNUAL REPORT 2019

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 2019

FOREWORD

Dear readers,

The Annual Report 2019 presents our scientific highlights from the country's important future fields. From molecules to finished products, we report on future-oriented developments and demonstrate the wide range of applications and the enormous potential offered by fiber-based materials and textile technologies.

Textile products and processes that we develop at the DITF Denkendorf are innovation drivers for many industries. They provide impulses in lightweight construction, medical and environmental technology, in the fields of regenerative energies, resource efficiency and mobility or in the classic areas of clothing and home textiles. As a companion in these fields of application, we shape the future with practical solutions and ideas.

Strengthening innovative strength

The most important task of the DITF is and remains the development of marketable products, processes and services for the economy and thus the orientation of our work to the needs of the industry. Especially small and medium-sized companies appreciate the DITF as an important research partner and supplier of innovative know-how. Therefore, more than half of the industry's revenue in 2019 was generated with small and medium-sized companies. At the same time, numerous ZIM projects contributed to strengthening the innovative power of medium-sized companies.

Further development of the DITF strategy

In connection with the DITF Strategy Process 2021, the past year was also marked by changes. The focus was on the further development of internal structures in order to make research across the entire textile value chain even more efficient.

So far, four competence centers have been established, which clearly structure the long list of competencies – from molecules to finished products – and the differentiated expertise at the DITF and bring them together in a thematically focused manner (see report on pages 12/13). Further competence centers will follow.

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

Focus Topics Digitization and Sustainability

While our research projects over many years have primarily driven technical innovations for higher productivity, greater effectiveness and flexibility, new thematic priorities have now been set. In 2019, the focus was on digitization and sustainability, and is likely to remain so in the coming years. There is hardly a project that did not address these issues and came up with comprehensive digitization concepts and/or the idea of sustainability. Digital technologies as well as biological and life science findings and processes are central drivers of progress, which we want to use consistently in their potential for our research fields.

Techtextil – Trade fairs and Co.

2019 was an eventful trade fair year – the diary was packed with numerous dates in Germany and abroad, including Techtextil/Texprocess in Frankfurt, ITMA in Barcelona, IFAI Expo in Orlando USA and MEDICA in Düsseldorf. For the first time the DITF exhibited at the ISPO in Munich and presented the Digital Textile Micro Factory.

In addition, we offered the industry a broad program of events. The SMART TEXTILES user forum at the Erwin Hymer Group in Bad Waldsee, the ITMA follow-up in Denkendorf and the ADD International Textile Conference in Dresden were among many other events special highlights and each opened an ideal forum to discuss our developments and research results and to form research partnerships on this basis.

Internationalization

The international activities were specifically expanded in 2019 to intensify the exchange with leading suppliers worldwide. The target markets were in particular the USA and France. An important step was the entry into the French Techtera cluster based in the textile region Auvergne-Rhône Alpes. At the same time, we were able to obtain recognition of the DITF as a public research institution by the French Ministry of Higher Education, Research and Innovation, which is associated with considerable tax breaks for French companies when commissioning our services.

2019 also brought us very sad news. In April, we had to say goodbye to Hans Hyrenbach, our long-standing Chairman of the Board of Trustees. As a passionate textile worker, Hans Hyrenbach had a decisive influence on the successful development of our research facility for two decades. He contributed to the fact that the future topic of technical textiles made of modern high-performance fibers moved into the center of research instead of classical clothing textiles.

We would like to thank our customers and partners for the trustful cooperation in the past year and look forward to future challenges and the exchange with you. With this annual report you can gain an insight into details of our research, ideas and innovations from the German Institutes of Textile and Fiber Research Denkendorf.

Your DITF board of directors

Prof. Dr.-Ing.
Götz T. Gresser

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

Peter Steiger

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> DITF points of contact

> Publicly funded research projects

> Published final reports, publications, lectures, press releases

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> Events, trade shows, exhibitions

> Patents

> Bodies, scientific advisory councils

Orders: info@ditf.de

DEUTSCHE INSTITUTE FÜR
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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 Engineering 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. In our fields of activity we belong to the world-leading research institutions.

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 COMPETENCE CENTERS

Joining forces. Strengthen strengths. Use synergies. With the establishment of four competence centers as part of the structural and strategic realignment, DITF is making its services and innovative strength even more effective

Prof. Dr. rer. nat. habil. Michael Buchmeiser,
Chairman of the Board

On the reorientation of the DITF

The implementation of the 2021 strategy for the DITF Denkendorf culminated in the foundation of competence centers at the end of 2019. This was based on several considerations and necessities. On the one hand succeed in finally eliminating all the duplications that had been created over the years, partly intentionally and partly unintentionally. On the other hand, it was the declared goal to bundle forces and to clearly present strengths, competencies and, above all, unique selling points to the outside world in the course of the structural and strategic realignment of DITF.

In a first step, the foundation of the Competence Centers Biopolymer Materials, Chemical Fibers & Nonwovens, Polymers & Composites and the Competence Center Textile ChemistryEnvironmentEnergy. On the one hand, this has enabled a stringent thematic focus within these centers, and on the other hand, it has brought together expertise from the fields of synthesis chemistry, polymer chemistry and physics as well as polymer and fiber technology with that from the fields of process technology, mechanical engineering and textile and process engineering. Thus, each competence center reflects the DITF's overarching unique selling point in many areas: the possibility to research and develop along the entire textile chain. The process of structural consolidation of the DITF is to be completed by the end of 2020 with the establishment of further competence centers and the reorganization of the remaining research and development areas.

Competence Center Biopolymer Materials

The DITF are one of the world's leading research centers in the development and production of technical fibers and materials based on biopolymers such as cellulose, chitin, keratin, alginate or lignin. The Competence Center Biopolymer Materials combines these research activities and reacts by focusing on the increasing importance of bio-based and biodegradable polymers. Their development makes a significant contribution to climate protection and a sustainable future.

With new dissolving processes, renewable biopolymers can be processed into high-strength, technical fibers which can be used, for example, as fully recyclable composite materials in lightweight construction. Current research projects deal with the production of cellulose and lignin-based carbon fibers, the further development of ionic liquids technology for the processing of bio-polymers and the processing of chitin for medical products.

Competence Center Polymers and Fiber Composites

The Competence Center Polymers and Fiber Composites deals with the production and further development of polymers for fibers, textiles and matrix systems as well as the optimization of textile processes and fiber composite technologies. The DITF is the only textile research institute worldwide that can rely on a continuous process chain – from matrix production and fiber/matrix compatibility to preforming, manufacturing and component testing. The close integration of polymer technology and process engineering in the competence center enables the effective development of competitive fiber composite materials and processes from laboratory scale to industrial maturity.

Current research projects include energy-, material- and cost-efficient process engineering for fiber composites, component, process and service life optimization for hybrid, multifunctional composites and the development of individual polymers for melt spinning, extrusion and injection molding.

Competence Center Chemical Fibers and Nonwovens

The development of man-made fibers and nonwovens for technical applications as well as the technologies for their production is the main focus of the Competence Center Chemical Fibers and Nonwovens. The center covers the entire range from melt spinning of fibers to the production of nonwovens in direct nonwoven processes and carding technologies. Special expertise in polymer chemistry and physics as well as in mechanical engineering forms the basis for fiber-based solutions in a wide range of applications, for example in lightweight construction, in environmental and energy technology, for smart textiles or especially in medicine.

The competence center is embedded in the DITF-wide certification for the development and production of polymers and textile implants according to ISO 13485:2016 with fiber and nonwovens production, partly in clean rooms. Current research projects deal with the development of new fiber functionalities, sustainable fiber alternatives and with thermo-plastic and material recycling processes.

Competence Center Textile Chemistry, Environment, Energy

The Competence Center Textile Chemistry, Environment, Energy combines the existing expertise in the fields of chemistry and process engineering for textile finishing of yarns and textile surfaces. In addition to the development of coated textiles, central topics include textiles as carriers for microorganisms, textiles for energy generation and for filter applications. The aim is to improve textile materials and processes in terms of functionality, energy-efficiency and ecology. Special know-how is available in the functionalization of textile surfaces, whether by finishing, modification, printing, coating or laminating.

The research focus currently includes the development of sustainable textile auxiliaries, environmentally-friendly textile-finishing processes, the use of digital process technologies for surface functionalization and the development of polymer layers on textiles as well as textile materials for renewable energies, for energy storage and transformation of energy flows.

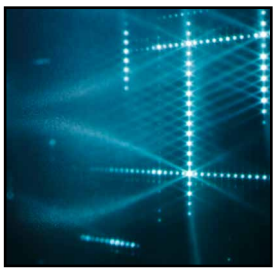
DITF RESEARCH FIELDS

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

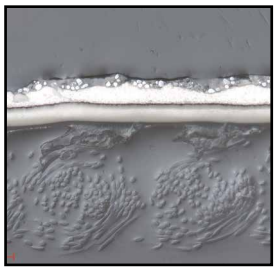
High-performance fibers and yarns

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



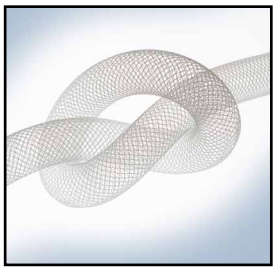
Smart textiles

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



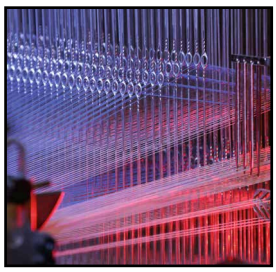
Textile finishing and coating

Development of functional technical textiles with new environmentally friendly technologies



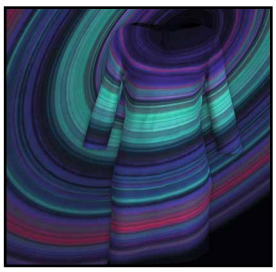
Medical technology

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

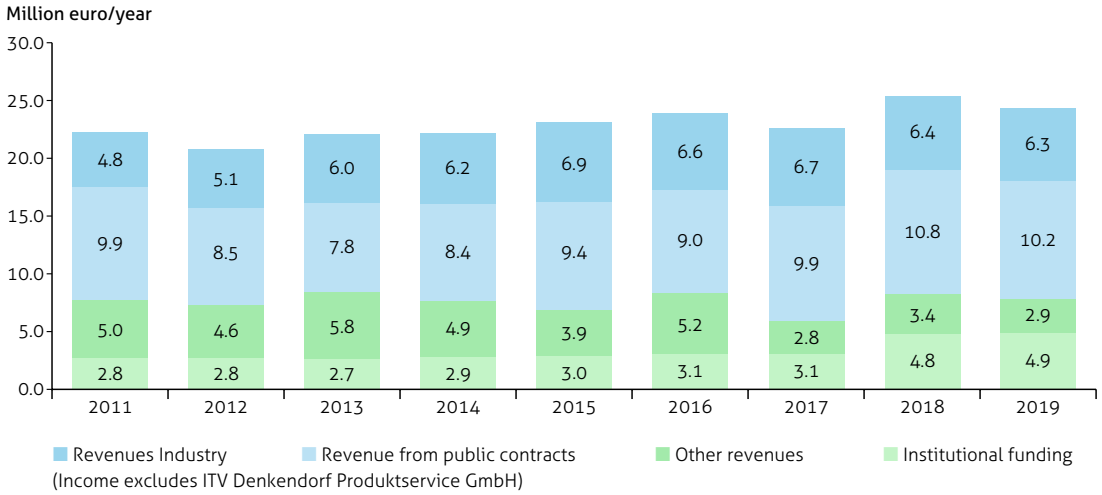
Fibers, structures and products e.g. for the automotive industry and for aviation and space travel technology

Clothing and home textiles

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

FIGURES – DATA – FACTS

Income DITF 2011 – 2019



Business development

Total income from ordinary business activities amounted to EUR 24.3 million in 2019, which was below the 2018 result. Public-sector orders and other income decreased compared to the previous year. In addition, there was also a slight decline in industrial revenues.

Institutional funding by the Ministry of Economics, Labour and Housing Baden-Württemberg increased slightly in 2019 and remained almost at the previous year's level with EUR 4.9 million.

In terms of industrial revenues, small and medium-sized enterprises play a particularly important role for the DITF. The share of SMEs in industrial projects in 2019 was approx. 52 %. The focus on small and medium-sized enterprises is also evidenced by the high number of ZIM projects, which accounted for 25.0 % of revenues from public contracts in the reporting period.

Employees as of 31.12.2019

DITF

235 employees
107 scientists* and engineers*
128 non-scientific employees
7 doctoral students
1 scholarship holder
67 students (Bachelor and Master students, graduate students)

ITV Denkendorf Produktservice GmbH

49 employees

Quality Management

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

The Biomedical Technology Development Division, the PET yarn and PGA nonwoven production division and the ITV Denkendorf Produktservice GmbH are certified according to DIN EN ISO 13485:2012. Scope: Design and development, production and distribution of absorbable and non-absorbable surgical suture materials, implants and wound covering 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

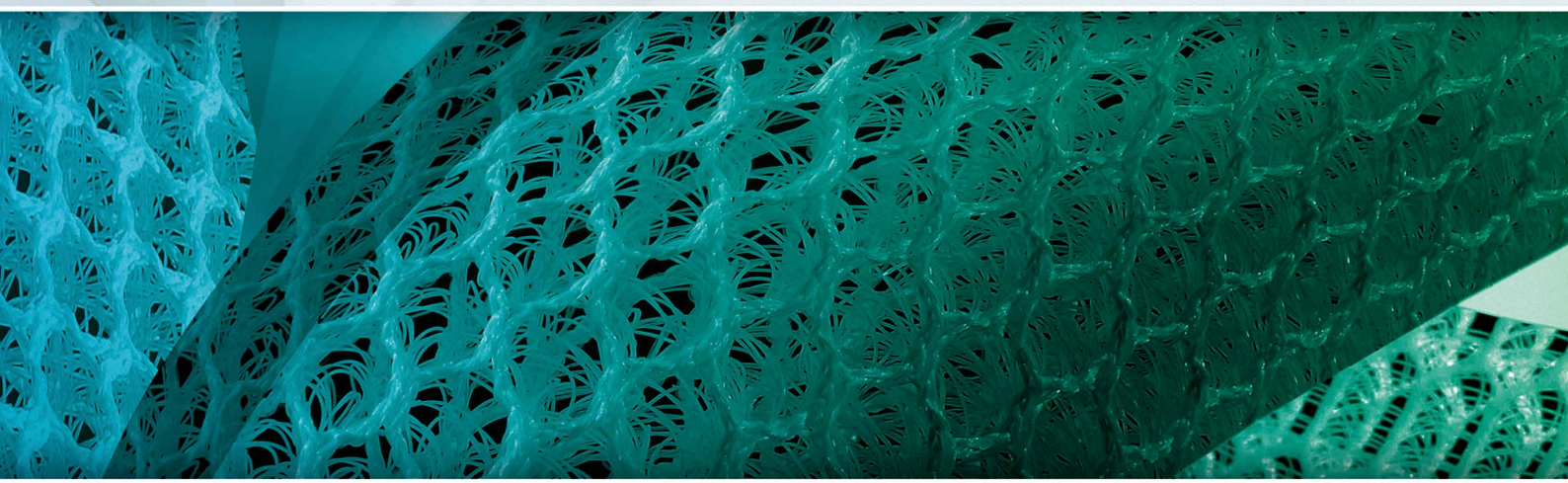
DITF co-founded the German Industrial Research Foundation Konrad Zuse e.V. This association represents the public interests of non-profit industrial research institutions in Germany and is open to all technologies and sectors. Its members include independent research institutions from all over Germany.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

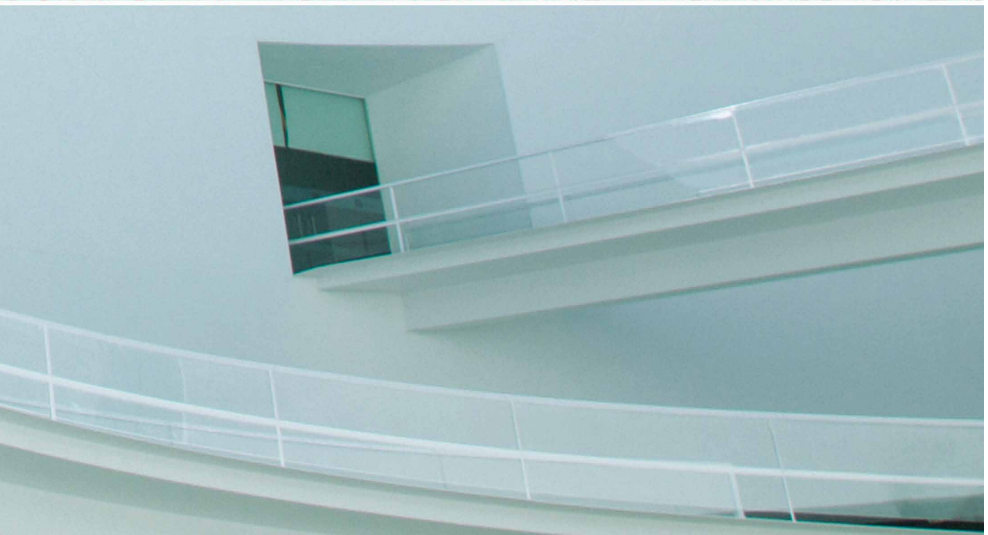
BioRegio STERN · MedicalMountains · TechnologyMountains · microTEC Südwest · Allianz Industrie 4.0 Baden-Württemberg

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



ARCHITECTURE AND CONSTRUCTION

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



> Textile facade elements: intelligent, light building shading
> Light-guiding textiles
> Smart textile construction elements
> Pneumatic textile actuators
> Autonomous living walls
> Textile moss walls for particulate reduction
> Optically transparent fiber reinforced materials
> Textile solutions for Smart Home & Smart Quarter
> AI in construction
> Sonic textiles
> New membrane materials for textile construction

Architecture and construction

The construction industry needs innovative approaches to develop their future tasks. To this end, the DITF are actively involved in the planning and design process of the International Building Exhibition IBA 2027 of the StadtRegion Stuttgart to provide textile support. 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.

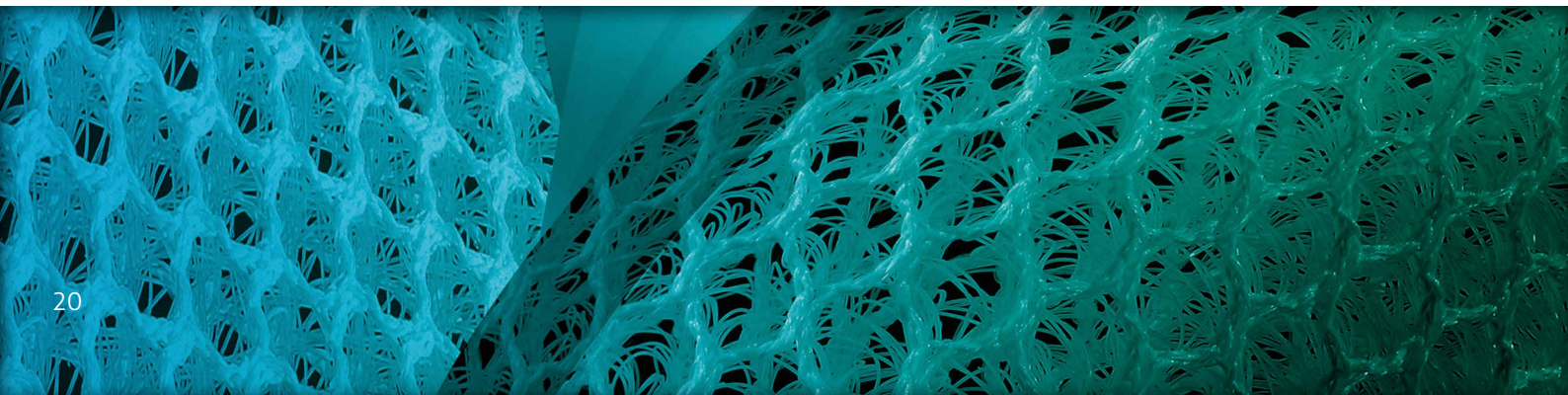
Functional, smart building textiles

Textile solutions to address these issues can be found, for example, in the development of new materials, structures and control systems for new parts, components and products. 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. In combination with AI solutions this potential opens up for the user. The DITF develop feasible, efficient solutions for this purpose that address the issues of post-compaction and create added value for the customer.

Textile solutions for redensification

The Denkendorf ResearchCUBE allows us to develop ideas; moreover, test and demonstrate new approaches, which then results in the rapid introduction of new products. New shading textiles achieve optimum light distribution in the interior of a building because even though they reduce glare, they direct so much valuable daylight into a room that artificial lighting becomes unnecessary. Integrated textile sensors measure the illuminance as well as control AI-supported textile-based actuators that adjust the shading depending on the position of the sun. Within the framework of the Mittelstand 4.0-Kompetenzzentrum textil vernetzt, companies are supported in implementing such AI-based applications. 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

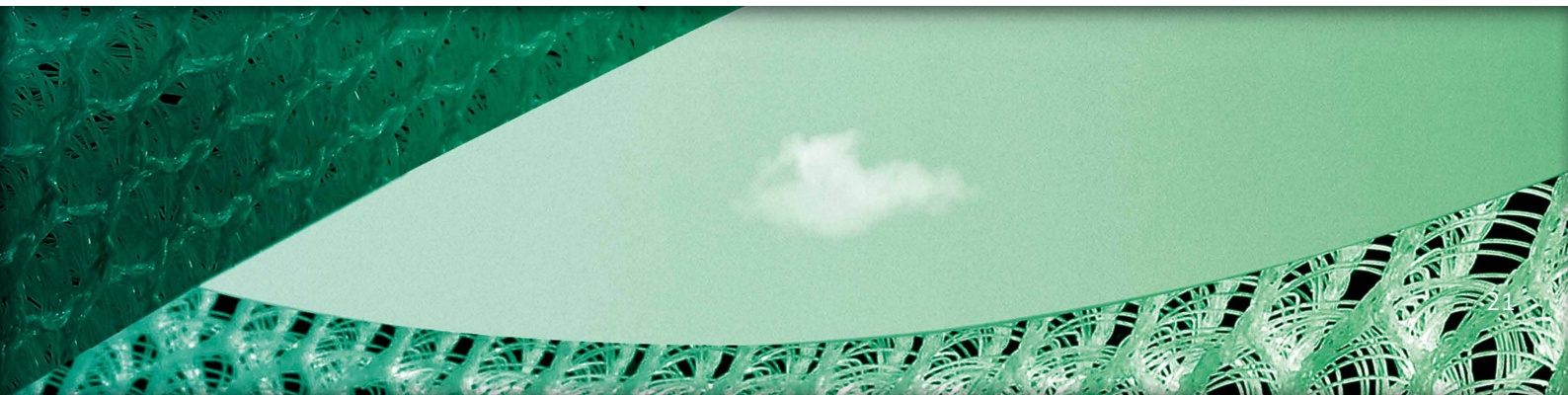
Fiber-reinforced composites have industrially relevant properties as a result of their great specific strength and rigidity; subsequently, they are becoming increasingly important for use in construction. Moreover, the orientation of the fibers, adhesion at the fibermatrix interface, as well as the many 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

Within the framework of the Collaborative Research Center (SFB) 1244, fully transparent fiber composites were successfully developed as load-bearing components in buildings and shells. Work is currently underway to integrate sensors into these fiber composites to generate a complex component that will detect deformation and 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. In this respect, the sensory structures will be printed on the fiber fabrics on the basis of a conductive paste (e.g. carbon black, silver, ...) e.g. by means of a screen printing process. 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.

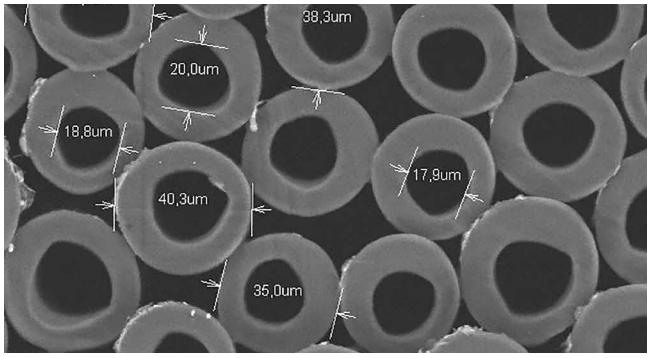
Following the sensor printing, these fiber-based sensors are to be fitted with electrical connectors and covalently embedded in a suitable polymeric matrix.



Facades made of biopolymers

Facade insulation has an impact on the environment in two ways. On the one hand, they reduce energy losses, and on the other hand, they themselves pollute the environment during their life cycle. The joint project EnOB: BioFassade takes up this topic and aims to improve the ecological balance by developing hollow fibers made of biopolymers and cellulose acetate with very high insulation properties.

In the project, an interdisciplinary solution is being worked out, which is based on the development of materials. It includes the production of the facade insulation elements and takes into account all constructional details up to the corresponding fastening system.



Cross sections of hollow fibers made of the biopolymer PLA

Renewable polymers in high-performance facade insulation

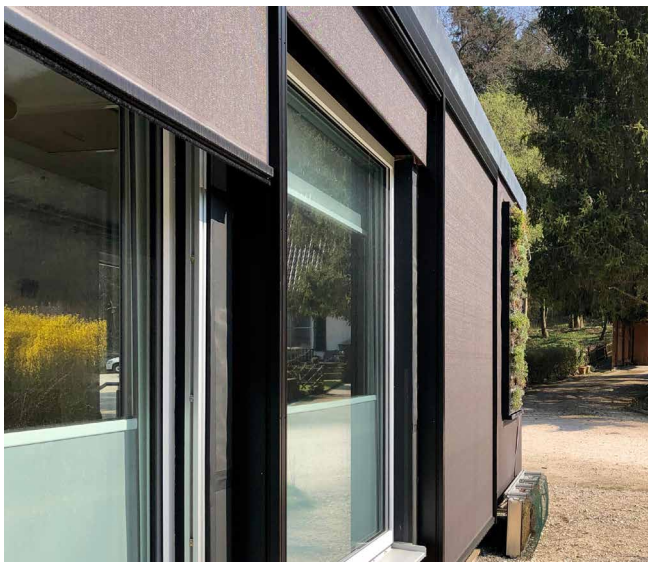
For this project, the DITF are producing biopolymer hollow fibers, which are processed into nonwoven composites using the FIM (Fiber Injection Molding) technology. Further tasks of the DITF are the modelling of the thermal insulation, the subsequent finishing of the nonwovens, the testing of biodegradability and life cycle assessment.

The material and component developments are supported by planning tasks, simulations and tests. The simulations include investigations into the load transfer of all components of the facade insulation system. Tests provide mechanical properties of the bio-polymers. The composite behavior is recorded and the connection between fastening technology and insulation element is checked. The construction-physical properties of the materials and the facade insulation element including fastening are simulated and validated with tests.

Use of AI in textile sun protection

Correctly coordinated internal and external sun protection makes an important visual and thermal contribution to the use of buildings. From a thermal point of view, external sun protection essentially serves to reduce the heating of rooms. However, under different circumstances, it can also be used specifically for solar gains in room heating. Internal solar shading is used to keep heat inside the building. The most important visual characteristics are the visual contact to the outside, glare protection, darkening as well as the visual protection that protects against unwanted glances.

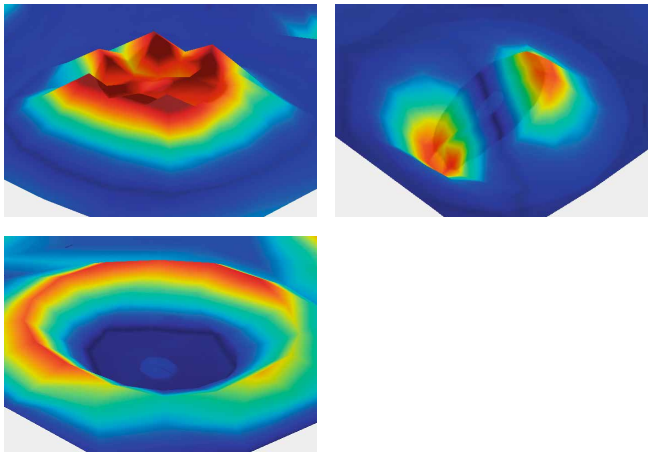
The respective prioritization of these aspects is determined by the current use of space and climatic conditions. A non-ideal allocation reduces the visual quality of use of the room and lowers the energy efficiency. During the periods when a room is not in use, the solar shading can be operated with thermal dominance. As soon as a room is in use, however, the visual requirements dominate. Both the room use and the climatic conditions are rapidly changing dynamic parameters. Classical control and regulation concepts therefore often lead to a lack of visual and thermal comfort. Therefore, a new approach is being researched in the DITF ResearchCUBE. By using AI for the control of interior and exterior sun protection, the currently rigid control and regulation concepts are to be improved in the future in such a way that the quality of living in rooms and energy efficiency are increased.



Intelligent textile sun protection

Low frequency sound absorption with textile resonators

By developing textile resonators, the sound absorption of frequencies below 200 Hz could be significantly increased. Textile resonators are vibrating textile surfaces with local variations in mass, such as an embroidered ring disk. The textile parameters as well as the applied mass enable a resonance frequency tuning of the system as well as a specifically variable damping. This novel sound absorber technology offers a substitution possibility for conventional porous absorbers, which require great depths for low-frequency absorption according to the law of mass. At a lower limiting frequency of 100 Hz, this depth is at least 85 cm. The developed textile resonators have defined eigenmodes and start to oscillate in resonance when a sound field hits them.



Three eigenmodes of the textile resonators

Significant improvement of sound absorption

The mechanical energy of the vibration is extracted from the sound field and converted into heat by fiber-fiber friction. In addition, air currents are formed through the pores of the textile surface and viscothermal losses occur. These effects significantly improve sound absorption, especially at low frequencies. This development offers a direct opportunity to cope with the increasing noise pollution in the context of ever increasing urban densification and to offer a sustainable city life of the future.

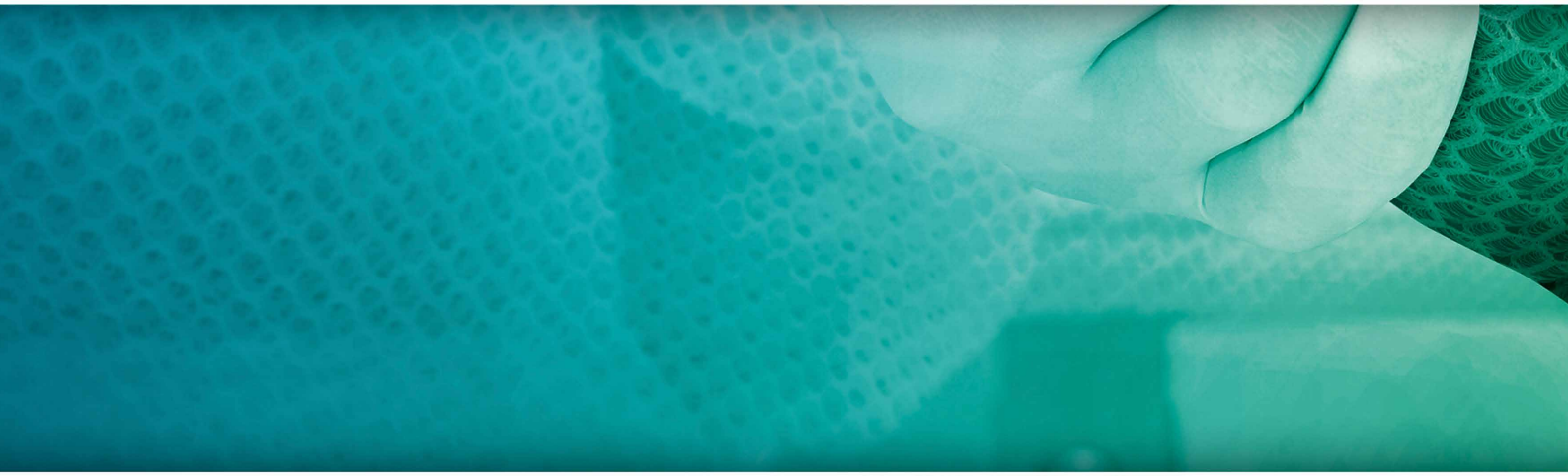
Reinforcement of prestressed concrete with cellulose filament yarns

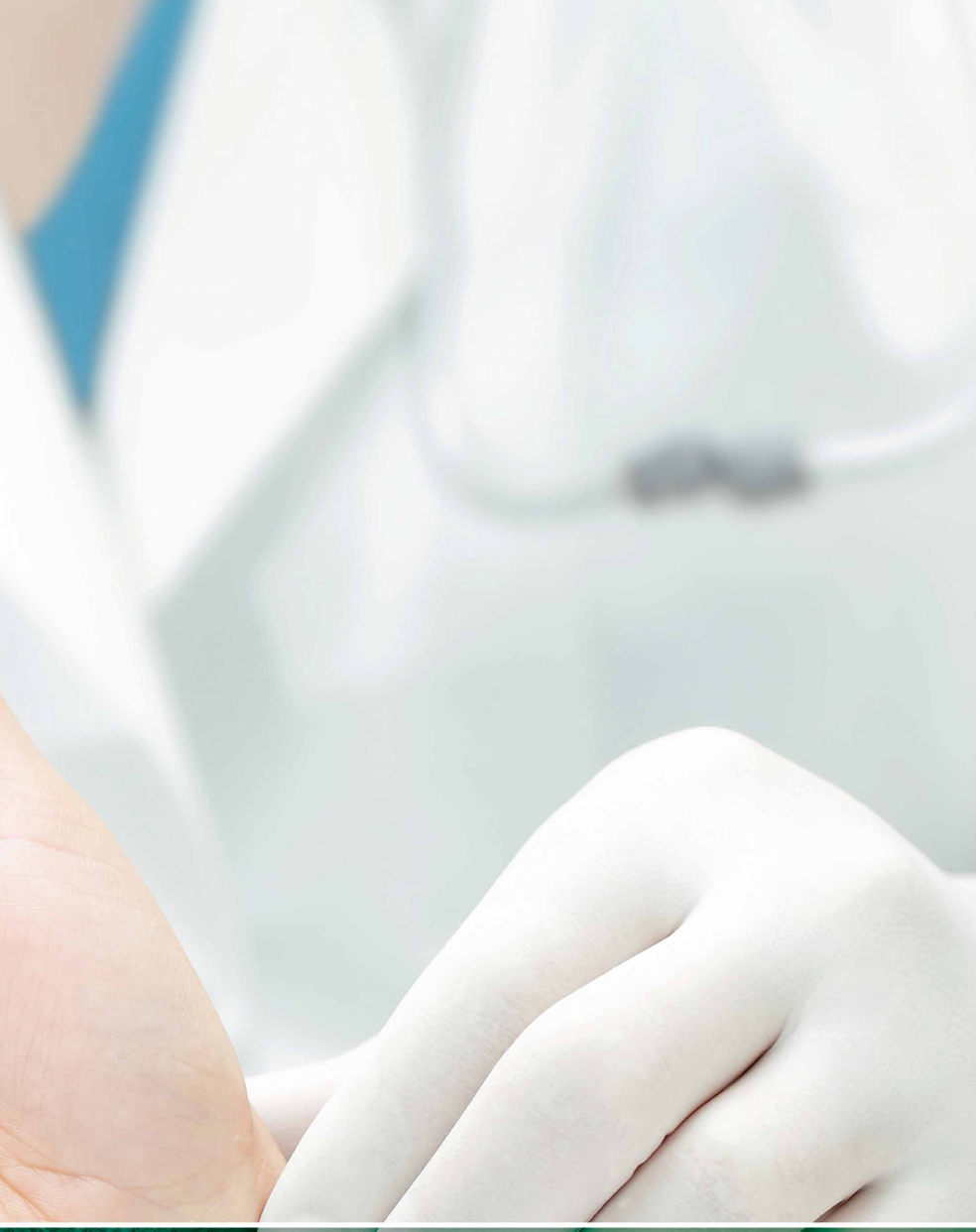
Prestressed concrete is a variant of reinforced concrete with an additional external longitudinal force. It differs from reinforced concrete in that the steel inserts, so-called prestressing tendons, are pre-stressed according to plan. By using these, the good compressive strength of the concrete is additionally exploited so that crack formation can be minimized and deflections are significantly lower for large spans.

A new type of prestressed concrete was developed at the DITF. The high performance fibers used for reinforcement are technical cellulose filament yarns. The direct application of established techniques for tensioning the cellulose fiber-reinforced concrete proved to be advantageous. Due to their high specific strength and good availability, cellulose fibers are a promising reinforcement material for building materials. For the first time, the DITFs have succeeded in fixing the cellulose fibers under tension in concrete elements and transferring the entire pretensioning force to the concrete element. Due to the good ductility of the technical cellulose fibers, a high working capacity can be introduced into the concrete as a tension force.

The cellulose fiber reinforcement offers significant advantages over the established prestressed concrete with steel reinforcement. In contrast to steel, cellulose fibers are not sensitive to corrosion. Consequently, there is no need for costly corrosion protection and repair work caused by corrosion is not necessary. Another advantage is the simplified disposal and recycling of the concrete parts, as there is no need for time-consuming separation of the reinforcements. In contrast to carbon fibers, cellulose fibers in carbon fiber-reinforced concrete show a very strong bonding to the surrounding concrete matrix, which results in very good material properties

Cellulose filament yarns embedded in concrete





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

Medical devices accompany us in many difficult phases of our lives and help us to heal or at least make diseases and injuries bearable. The importance of protective and therapeutic measures has become particularly clear to us since the corona pandemic threatened mankind worldwide. In order to protect as many people as possible from an illness, textile protective equipment in particular is in great demand. The DITF and many research institutions worldwide are taking this as an opportunity to develop new products that can protect us from the invisible viruses.

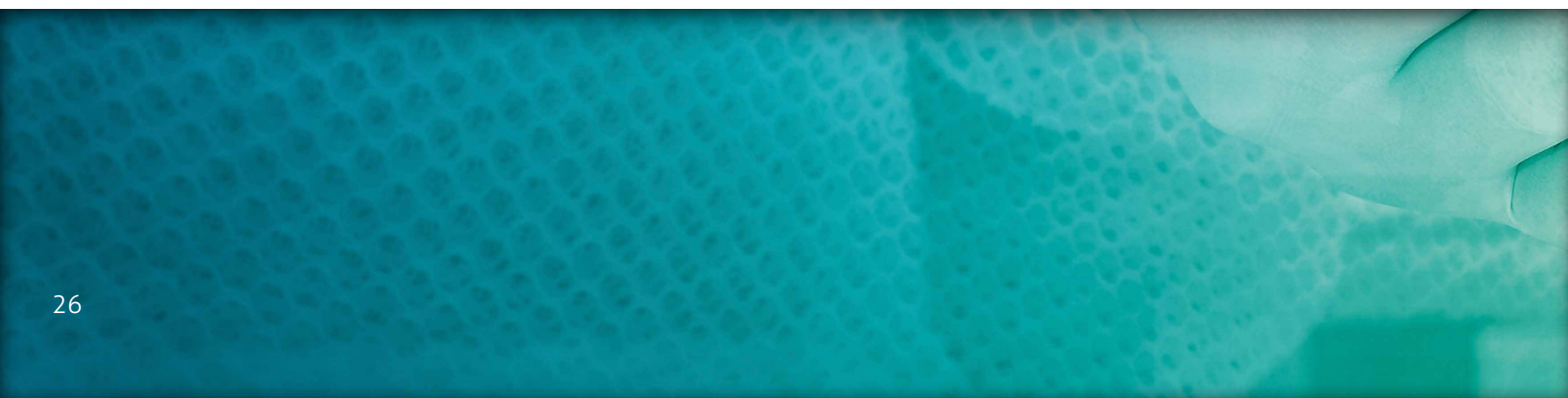
Medical technology is facing great challenges: in an effort to provide sufficient capacity for the treatment of Covid-19 patients in hospitals, other areas of medical care have been cut back, with serious consequences for the entire industry, which therefore anticipates significant sales losses in many areas. Nevertheless, the final implementation of the new Medical Device Regulation was postponed by one year, to 26.05.2021. The implementation of the regulatory requirements is a major challenge for many companies and even established companies have to massively streamline their product range. At the same time, the pandemic has highlighted the vulnerability of our globalized economy to essential supply chains and has triggered a discussion about keeping relevant production facilities in the home country.

Digitization of production

Digitization is becoming an increasingly important factor for production. It enables the fabrication of products with a particularly high quality, purity and traceability, which is especially required in medicine. At the same time, production is also very cost-effective due to the high effectiveness of the digitally supported production techniques. In a digital twin, for example, it is recorded how materials in production can change in each process step. This not only enables the processes to be optimized, but also makes it possible to coordinate them much better.

Digitization in therapy

Not only the production of medical devices but also the therapies themselves are becoming increasingly digitalized. Telemedicine is being further expanded, ward rooms in hospitals now resemble control centers of power plants, and doctor's visits via video are not only found in sparsely populated districts. Above all, the continuous monitoring of healing processes offers a more targeted and safer therapy. For example, an intelligent wound dressing was developed in a Europe-wide joint project, which can significantly reduce the stressful changing of dressings and hospital stays by such monitoring.



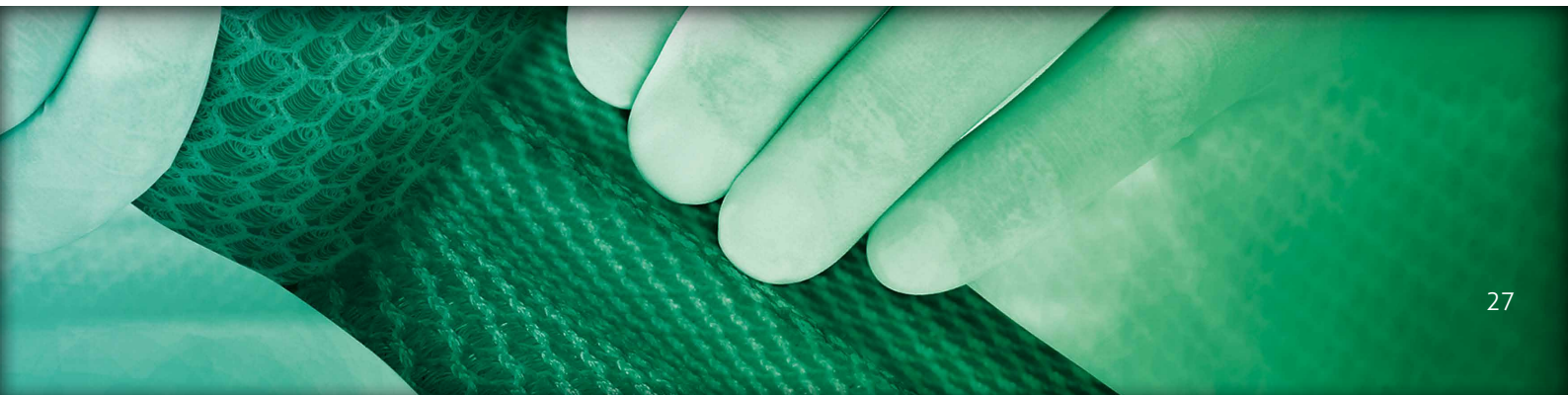
Biomaterial Chitin

On the material side, too, new approaches are constantly being pursued. Chitin is a material that is widely used in nature and has proven to be very effective, e.g. in the shells of crabs and the wings of beetles. The fact that chitin has hardly been used in medicine and other technical areas so far has to do with its difficult workability. This problem has now been successfully solved at the DITF and offers a wide range of applications (e.g. in the field of wound dressings) for this inexpensive material; comparable to chitosan, which, however, has to be processed from chitin at great expense.

Bone replacement

The requirements on implants are also increasing: in addition to replacing damaged or lost tissue, modern implants are increasingly aimed at using and guiding the body's great regeneration potential in order to create structures that are as natural as possible. The bone replacement presented in the following report has this potential. The pore structure allows the ingrowth of small blood vessels which is necessary for large bones. It could also be shown that the material allows the binding and spreading of bone cells – the first step for a successful regeneration of a bone defect.

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

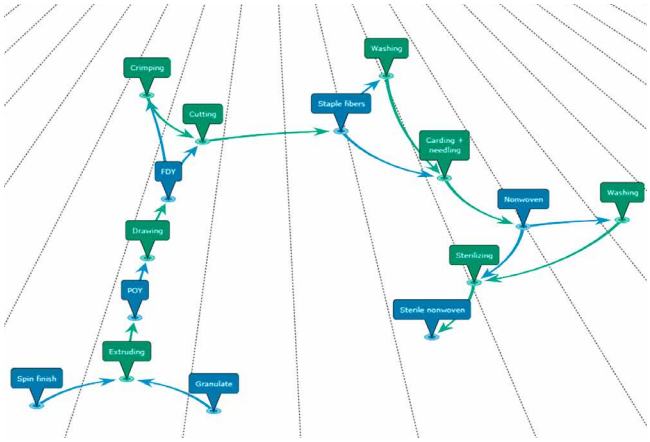


Digital material twins of implants made of polymeric non-woven fabrics

In order to implement the goals of Industry 4.0, it is not enough to determine the properties of materials and products by various material testing at various points in the value chain. Rather, a detailed description and complete recording and networking of all information arising in the product life cycle is necessary.

Material data rooms

A so-called material data space makes an important contribution to this. In it the digital material twin of each material or product can be represented without having to completely redesign the company's IT landscape. The digital material twin facilitates to make concrete statements about the current state and history of its counterpart in the real world. As part of a project funded by the state of Baden-Württemberg, the DITF, in cooperation with several Fraunhofer Institutes and the NMI Reutlingen, are developing a methodology for setting up a material data space for the representation of digital material twins. The concrete implementation will be carried out for implants made of polymeric nonwovens.



Nonwoven production – processes and materials

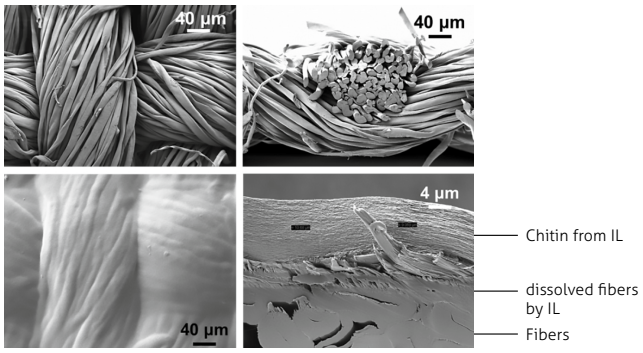
All materials within the complete process chain are taken into account, starting with the extrusion of the polymer, the production of the staple fibers and the nonwoven up to the subsequent testing processes to evaluate the biocompatibility. The contained information on processes and materials as well as the linked raw data enable the traceability required by the Medical Device Regulation (MDR) and form the basis for the use of artificial intelligence methods to determine the dependencies between product characteristics and process parameters.

Development of cellulose/chitin films and coatings for medical devices

In an ongoing research project, coatings and films made of the two biopolymers most commonly found in nature, cellulose and chitin, have been developed for medical applications. A direct dissolution process in ionic liquids enables the simultaneous processing of cellulose and chitin. The solvent is removed with water and is fully recyclable. Thanks to the pseudoplastic behavior of the cellulose/chitin/IL solutions, they are ideally suited for processing by means of doctor blade technology. In this way, stiff or flexible transparent films with a homogeneous structure were produced, which are soft, elastic and structurally stable after rehydration.

For the coating tests different substrates (nonwovens, fabrics, foams) were selected. The coatings showed good adhesion to viscose, cotton and polyurethane. The water retention capacity was increased from 40 % to 240 % compared to the substrate. In addition, the water vapor permeability was still given.

The films and coatings based on chitin are cytotoxically harmless and not antibacterially effective. Depending on the condition of the wound, moisture can be transferred to the wound or excess exudate can be absorbed. The dressings, which are soft, structurally stable, elastic and easy to drape when moist, allow good adaptation to the wound base and thus secure wound closure. In addition to use as a moisture-regulating wound dressing for non-infected wounds, wound care of infected wounds is also possible after appropriate addition of the active substance



SEM images of uncoated cotton fabric (top) and cotton fabric with chitin coating (bottom)

Intelligent wound dressings for chronic wounds

Chronic wounds mean a severely restricted quality of life for affected patients and high treatment costs for the healthcare system, which in the case of ulcus cruris, for example, amount to 10,000 euros per patient per year. In Germany about 890,000 people suffer from chronic wounds, worldwide about 4 million.

ULIMPIA
ULTRA-SOUND BODY PATCHES

In the Ulimpia research project, the DITF, in cooperation with numerous German and European partners from industry and research, are developing innovative materials and microelectronics for medical wound dressings that objectively measure and continuously record the pathology and healing process of chronic wounds. The figure shows a functional model installed in the laboratory. A wound dressing made of nonwoven and superabsorbent material contains a knitted fabric with sensor yarns that change their electrical resistance depending on temperature and their capacity depending on moisture.

Determination of the moisture on the laboratory sample Wound covering with sensor yarns

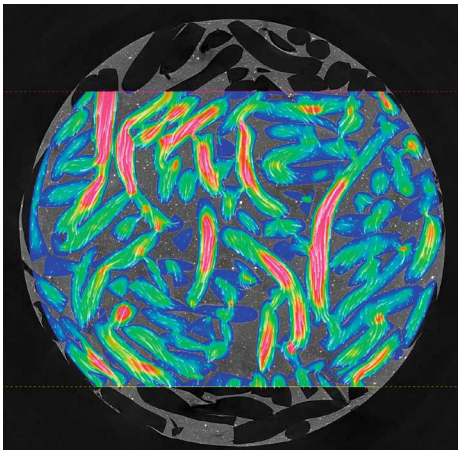
In the further course of the project, pH sensors will be integrated into the wound dressing and possible applications of ultrasound technologies in the treatment of chronic wounds will be investigated. The aim of all technical developments is to develop intelligent wound dressings that detect complications early, reduce dressing changes, inpatient hospital stays and treatment costs and improve the quality of life of patients with chronic wounds.

Penta

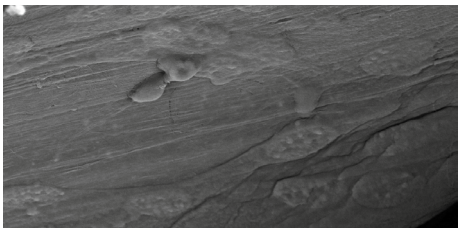
The Ulimpia project is part of the European PENTA cluster for research and development in the field of microelectronics in the forward-looking thematic areas of Industry 4.0, autonomous driving and intelligent medical technology.

Novel resorbable and fiber-based bone replacement material

Bone transplantation is still the standard treatment for bone defects, e.g. after tumor removal or accidents. However, this approach has considerable disadvantages, such as a lack of or too little porosity for the ingrowth of blood vessels or a theoretical risk of disease transmission in allografts. An alternative to bone transplantation is the replacement of missing bone with bone replacement materials that accelerate healing and ideally restore the properties of natural bone.



µ-CT Image with flow simulation of the interconnecting pores of the bone substitute material



REM image of SaOs-2 cells after 11 days in bone replacement

For this purpose, a resorbable scaffold with high porosity was designed as a bone replacement material. The interconnected pores of sufficient pore size allow the ingrowth of osteoblasts and vascularization. For this purpose, water-soluble polyvinyl alcohol fibers (PVA) and caprolactone fibers (PCL) functionalized with hydroxyapatite (HA) are sintered together and the water-soluble core component is dissolved out. What remains is an absorbable framework with high porosity. At µCT the interconnectivity of the pores is shown by a flow simulation. The improved cell adhesion and migration of osteoblasts into the scaffold and an osteoinductive effect could be shown in cell biological studies. Thus, this new bone replacement material is a promising approach for the use as framework for bone regeneration.

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 (FRP) are successfully applied in the most diverse areas of technology. Their advantages include superior structural robustness and rigidity combined with low weight, high resistance to corrosion, as well as outstanding fatigue strength. Apart from the expensive carbon fibers, which are mainly used in aircraft construction and the sports sector, the long-established inexpensive glass-fiber composites are still finding additional areas of application. The high cost of raw materials and production for carbon components act as an obstacle, the primary aim here is the so-called hybrid (mixed) construction employing steel, aluminum, magnesium, and FRP. The goal is to achieve optimal performance and costs.

An example is the roof rail of the new BMW 7 Series, which is manufactured by way of composites construction from woven CFRP (crash performance, weight) and steel (crash performance, connection of the spar to the car body). The use of new weaving, multiaxial and braiding techniques enables the production of highly integrated textile preforms that supersede the joining of individual fiber layers and exhibit superior crash characteristics as a turbine blade for instance.

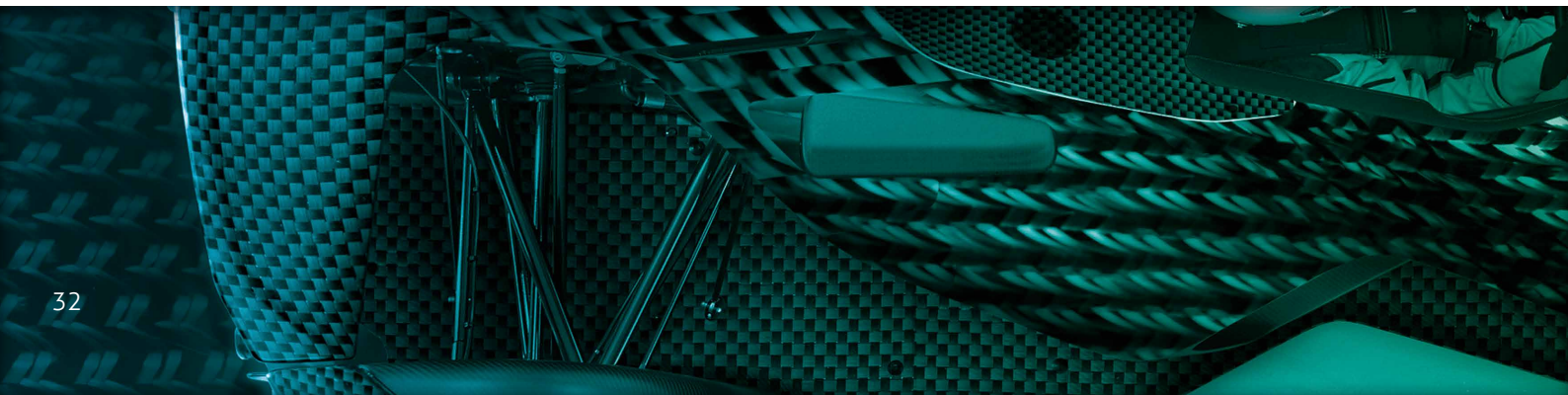
Improved matrix systems

A wide variety of improved matrix systems are being developed and characterized alongside the advancement of highly integrated textile reinforcements. The goal is to design matrix systems that are safe to process and produce favorable mechanical properties. The project "Fast Matrix" developed a thermoplastic matrix, which polymerizes very quickly in situ displaying excellent wetting of the fibers.

ARENA2036

The 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 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.

The follow-up project strives for significant further improvements of the "digital fingerprint" and the "digital factory" 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.



Exchange of results

Research results in the area of mobility can also be used in the field of construction – and vice versa. The DITF provides 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.

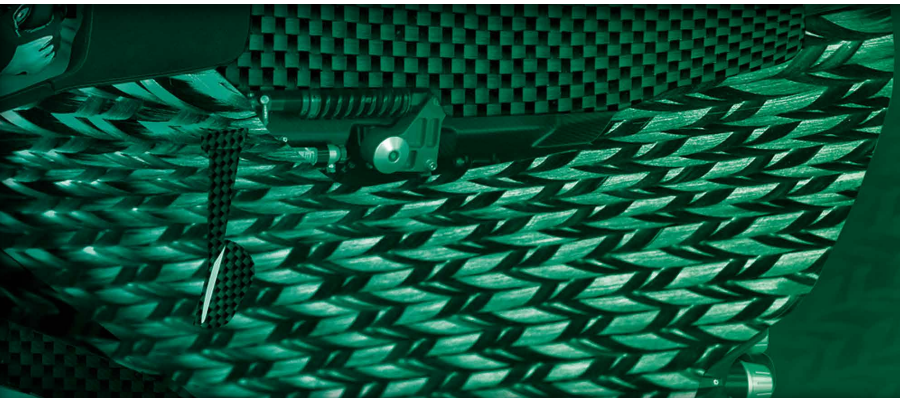
Primary objective: weight savings

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 to 20 %.

Recycling

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 creation of systems and products that have received global recognition. This proved to be highly popular in the recycling workshops organized by the DITF.

Exploiting the use of the favorable properties and outstanding environmental performance of fiber-reinforced composites further requires 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 the Carbon Composites e.V. (CCeV) and thus unite the expertise of various faculties in workshops and conferences.



Continuous component monitoring by means of piezoelectric multilayer fabrics

One form of damage to fiber composite plastics (FRP) is delamination. It is often not detectable by visual inspection. The detection of such defects requires complex non-destructive testing methods such as ultrasonic testing or computer tomography. In order to avoid these costs, sensor technology is to be integrated directly into such components in the future. Conventional sensor components, however, represent a foreign body in the amplification structure and can thus form a weak point in the component. The same applies for sensor fibers that are usually significantly thicker than the reinforcement fibers.

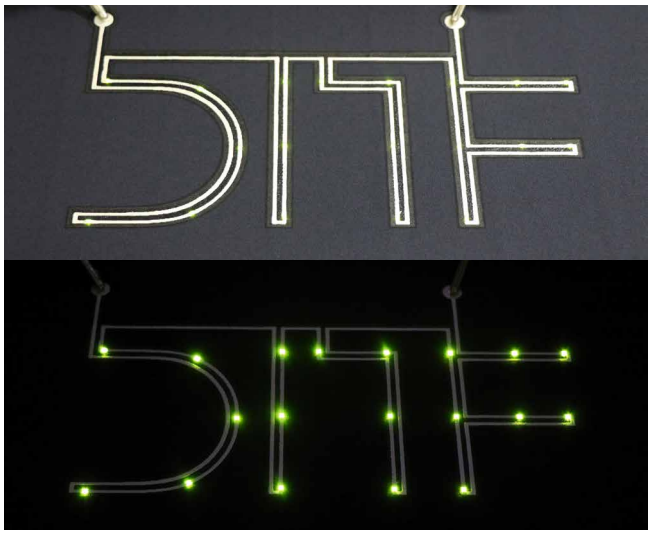
Production of a sensory multilayer fabric

Within the scope of an IGF research project, a fabric-based bending sensor system was developed as part of the textile reinforcement structure of FVK and characterized with regard to its electromechanical properties. Due to this sensory multilayer fabric structure no negative influences on the mechanical component properties arise. With the help of textile sensor systems based on multilayer fabric, possible overloads during operation can be detected in the future, damage can be avoided or detected and thus maintenance, repair and downtime costs can be reduced considerably. The integrated sensor technology enables continuous monitoring during operation of dynamically-loaded components and additionally guarantees the safety of the component. In two follow-up projects, the sensor reinforcement fabrics will be optimized for use during component manufacture (process monitoring) and for use as energy recuperators for generating energy from vibration and waste heat.

Stretchable protective layers for Smart Textiles

The increasing use of textile materials with electrical and electronic elements ("smart textiles") goes hand in hand with rising demands on manufacturing processes, functionality and durability. A major obstacle to the industrial implementation and marketing of many smart textiles developments has so far been the mechanical and chemical sensitivity of the conductive structures, especially in the case of flexible and stretchable textiles.

Within the framework of the joint industrial research project, the application potential of protective coatings for smart textiles components with the combined property profile of flexible, water vapour-tight, wash-resistant and abrasion-resistant is therefore being investigated. By adding water-based binder systems with phyllosilicates, the chemical barrier effect of the protective coatings is increased and at the same time application by screen printing is made possible. The precise arrangement and positioning of these thin diffusion-inhibiting layers in relation to printed conductors and the development of an adapted contacting method allow for the screen-printed production of smart textiles demonstrators to prove their functionality.



Smart Textiles-Material with protective coating

In order to turn technical developments into real, successful innovations, possible applications for various fields of application are systematically investigated and consolidated in markets with high potential. Market analyses are then carried out for these.

Textiles on the exterior – the car of tomorrow

In view of the increasing traffic volume and high air pollution, micro electric vehicles of the micromobility class, which are used for the first and last mile in both urban and rural areas, represent a great opportunity. The use of textiles is trend-setting in this context: by saving the overall mass, fuel efficiency can be improved for greater range and, in the case of goods transport vehicles, a higher payload is possible. In addition to the expected lower mass, another advantage of textiles in exterior applications is seen as the possibility of functionalization by means of sensors and actuators. The flexibility of the cover material and a new, unfamiliar feel also create potential as a novel design element.

Textile-covered car door with functional fabric

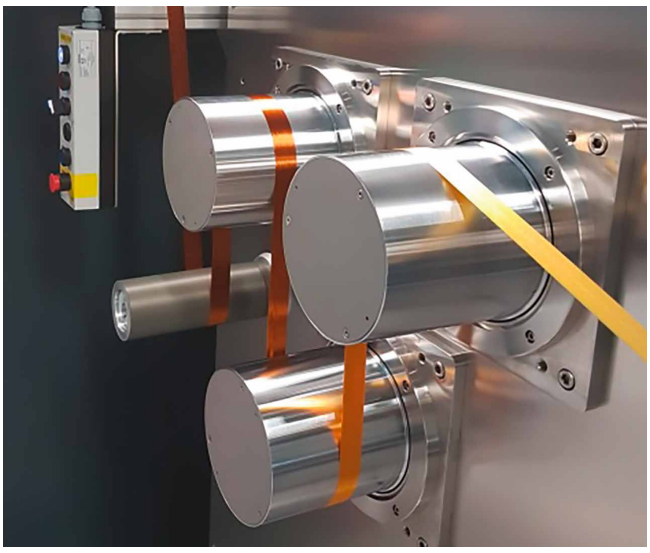
The research project "TexExIdentification, Evaluation and Demonstration of Meaningful Applications of Textiles in the Exterior of Vehicles" was initiated as part of the SME Mobility Initiative of the Baden-Württemberg Ministry of Economics, Labor and Housing. The task of the DITF is to test a wide variety of textiles for their suitability for exterior applications. In doing so, the work is always based on the legal framework conditions in order to enable a later series application of the project results. For a higher diversification of the implementation, the project is divided into two sub-projects: Passenger traffic and goods transport.

Cost-effective carbon fibers due to low-pressure stabilization

As part of a new, energy-saving production concept for the manufacture of carbon fibers, the DITF have developed a low-pressure stabilization furnace in cooperation with centrotherm international AG in Blaubeuren. The high costs in the production of carbon fibers have so far mainly been derived from the energy costs incurred during stabilization (oxidation) and subsequent carbonization at high temperatures. With the help of low-pressure technology, the new furnace allows for the first time to control the process atmosphere and to exactly reproduce the heat release of the precursor fiber during stabilization. The result is not only qualitatively improved, particularly homogeneous fibers, but above all a high energy saving of up to 70 % compared to the standard process.

From laboratory to industrial scale

The current laboratory facility can stabilize up to six fiber bundles simultaneously in the plant. A first industrial 50 k precursor (a bundle of 50,000 filaments) could also be processed with high throughput. The plant can process a maximum of 3 x 50 K precursor. This means that the practical hurdles for scale-up to industrial scale have been overcome. The new technology will quickly reduce the cost of carbon fibers from the standard raw material polyacrylonitrile by up to 40 % and thus open up many new applications.



50 K polyacrylonitrile precusor at the outlet of the low pressure furnace

ENERGY, ENVIRONMENT AND RESOURCE EFFICIENCY

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

- 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
- Use of artificial intelligence for good parameter setting of finishing machines
- 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 and systems for improved energy, environmental and resource efficiency – with and for their industrial partners – make the DITF essential research partners in this area. The results are sustainable products and services for a variety of applications. Filter and membrane materials for air and water purification, lightweight construction, insulators, sealants, as well as insulants for buildings and textile-based solar cells are just a few examples of the broad research portfolio at the DITF institutes. Current research topics focus mainly on material substitution, material efficiency, use of artificial intelligence 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. Recent work deals with safety and environmental aspects of solar cells using biopolymers. Another significant contribution of fiber-reinforced composites is in the development of wind turbine blades.

Textiles for environmental protection

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

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

Sustainable fibers and composites

The sustainability of textile products is a central issue in our society and is currently undergoing a strong collective change. Given the discussion on microplastics in surface waters and oceans, our research on natural fibers and polymers from renewable resources, which are also readily biodegradable or recyclable, is of vital importance for the future. Natural fibers from wood, hemp or algae play an enormous role in the production of textiles and their ecological and economic recycling. Further work includes the processing of natural fibers into high-performance yarns using state-of-the-art technology as well as the development of new filter materials and composites made of cellulose and 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. Our research focuses not only on various modern manufacturing processes but also includes product cycle analyses and how these affect the properties of the materials.

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

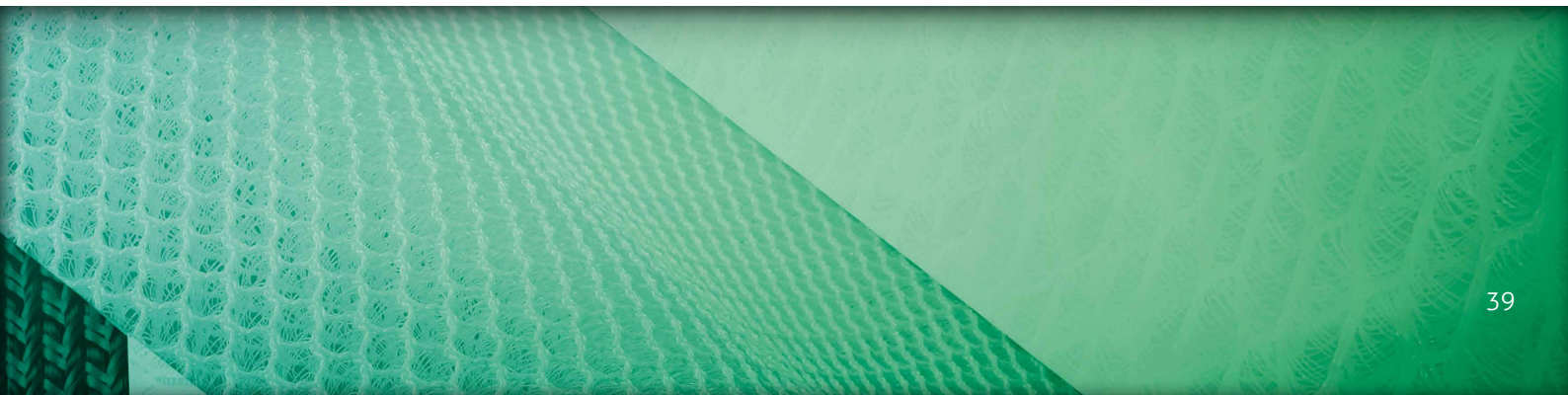
Often, these developments are accompanied by a life-cycle analysis to quantify both the consumption of our natural resources as well as the impact on the environment.

Energy consumption in textile manufacturing

Textile finishing and coating constitute the most energy-intensive processes in textile manufacturing. Thus, there is a need to review new technologies for their energy-saving potential. Such review includes the commissioning of cross-linking systems of solids without solvents and reactive hot melts as well as the use of 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 in drying and achieve excellent properties. These include curing through the use of electron-beam technology and ultraviolet light based on LED.

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



Fine dust catcher in modern, textile design

In cooperation with the companies Officium and Essedea as well as the Institute of Combustion and Power Plant Technology at the University of Stuttgart, a textile fine dust catcher system was developed at the DITF. The principle is based on a wet scrubber. A spacer fabric made of innovative and chemically-resistant fibers ensures the efficient separation of fine dust from the ambient air. Due to its three-dimensional, bionically-inspired net structure, the knitted fabric offers the best conditions for the gathering and binding of dust particles to water droplets. It thus forms the basis for a new generation of wet scrubbers for urban environments that require fewer resources for construction and operation than alternative solutions. At the same time, the development requires less maintenance, as the spacer fabric is continuously cleaned of collected dust with water.

Demonstrator of the fine dust collector in Stuttgart

In tests in the pilot plant, excellent air cleaning results were achieved with airborne model dusts. In accordance with surface topographical and fluidic objectives for the separation of fine dust, spacer fabrics of different structure and geometry were developed and tested.

Based on these results, the most efficient spacer fabrics from Essedea were selected and used for field tests. As soon as the results of the field tests are available, they will be extrapolated to determine the required functional textile area for reducing the fine dust pollution of a larger settlement or neighborhood.

Polyester fibers – 100 % bio-based from the chicory root

The leaves of the chicory have found wide use in our kitchen. The root is usually removed or ploughed under in the field. It contains a valuable substance – inulin – which can be used as a starting product for the synthesis of polymers. This offers an alternative to petroleum-based synthesis and does not interfere with the food chain, but increases its degree of utilization.

In cooperation with the Technical University of Munich, the Fraunhofer-IGB and the University of Hohenheim as well as several industrial partners, the DITF is researching the entire production process from the root to the textile product within the framework of a BMBF project under the sign of bioeconomy.

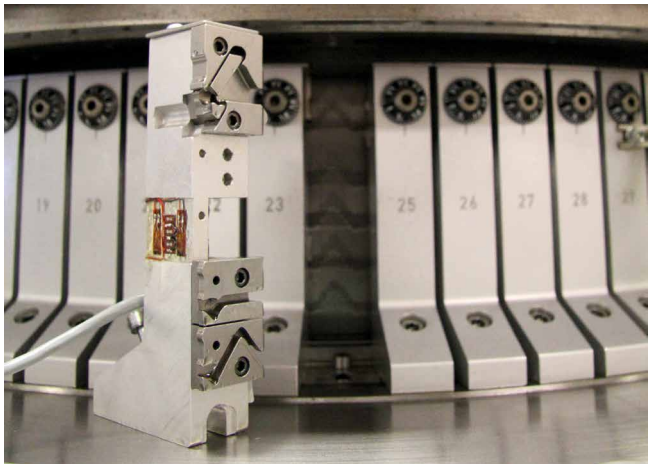
PEF – the new polyester fiber as a supplement and alternative to PET

The DITF have successfully demonstrated the synthesis of high molecular weight polyethylene furanoate (PEF) in pilot plant scale. PEF can be processed into fibers on common production lines. For the fiber partner TREVIRA, different qualities were spun, stretched and textured, which were delivered to the application partners Mattes & Ammann for knitwear and Fiber Engineering for voluminous nonwovens for upholstery applications. Even the highest requirements for a PEF fiber in the application as tyre cord for a 100 % bio-based tyre could be achieved with regard to the fiber manufacturer PHP Fibers and the end user Continental. The high raw material price still stands in the way of mass application. In addition, many new questions have arisen so that the consortium has submitted a follow-up application to the BMBF.

Knitted fabric from textured PEF yarn
(polymer & yarn: DITF; knitted fabric: Mattes & Ammann)

Data-driven resource efficiency on circular knitting machines

Due to the high quality standard of technical and non-technical knitted fabrics and the high stresses and strains placed on material and machine parts by increasing production speeds, resource efficiency on circular knitting machines is of particular importance. At the same time, awareness of the ecological footprint is growing, and the consumption of energy and operating resources is today not only cost-relevant but also imaginative. Knowledge of the relationships between the characteristics of the input and output materials, machine condition, wear and consumption of resources is therefore also a prerequisite for resource-efficient production processes on knitting machines.



Modified lock segment for measuring the sinking force

In a current research project, we are correlating coulier forces, machine vibrations, temperatures in the cam grooves and yarn tensions with the oil and energy consumption of the machine. For this purpose, a measuring system was set up which stores the process data in a time series database so that they can be efficiently processed and analyzed by machine learning algorithms. First of all, characteristic scenarios are investigated in the DITF laboratories in order to use the measuring system in industrial applications under real conditions. In the production environment, the necessary data sets for data-based models will then be generated. The far-reaching and in-depth information and knowledge extraction from data will enable resources to be used more efficiently in the future. Thus, Big Data Analytics will be used in the sense of Industry 4.0 to enable individual, knowledge-based, automated and resource-efficient production in SMEs.

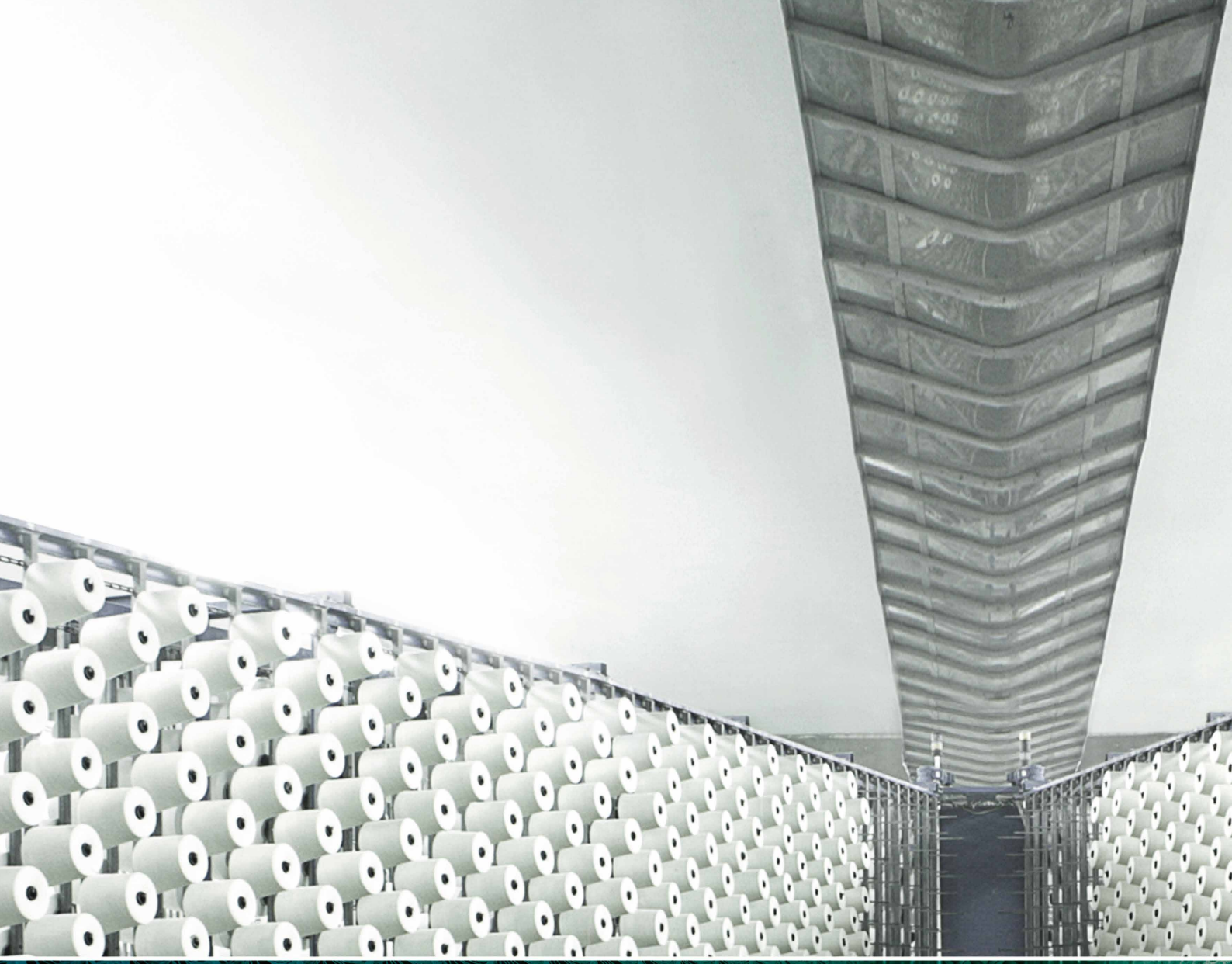
Sustainable products from 100 % SeaCell™ – diaper, sleeping bag

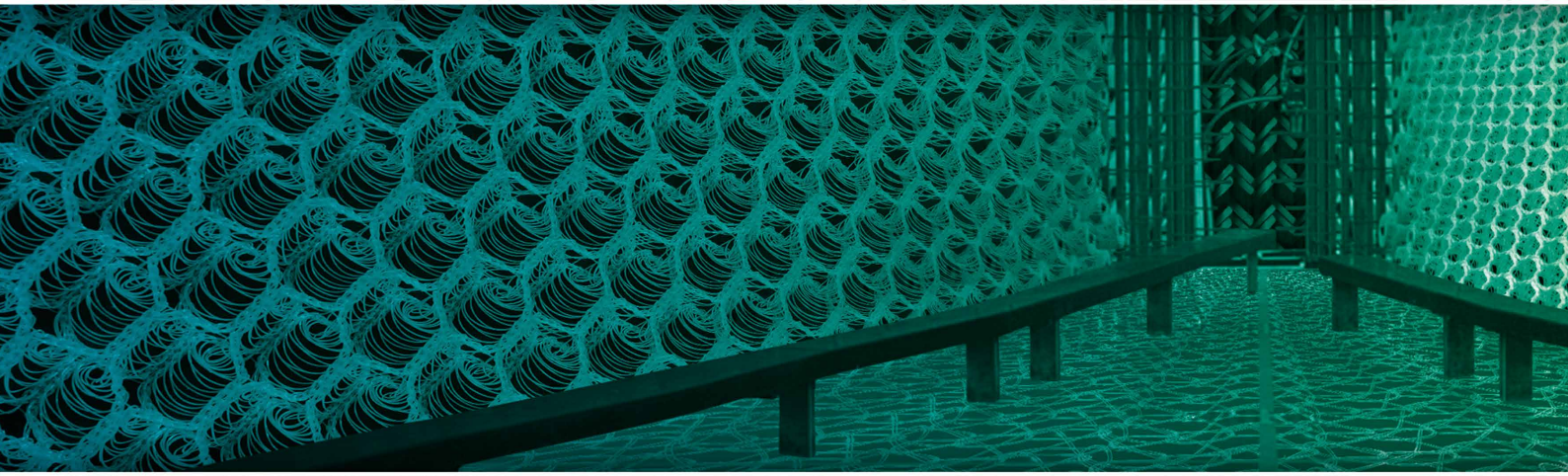
SeaCell™ is a completely biodegradable, extremely absorbent, breathable and naturally anti-bacterial cellulose fiber made from eucalyptus wood and brown algae extracts. It is manufactured using the Lyocell process. Within the scope of a master thesis two monomaterial products were developed with this fiber, a sleeping bag without zipper and buttons and a reusable diaper.

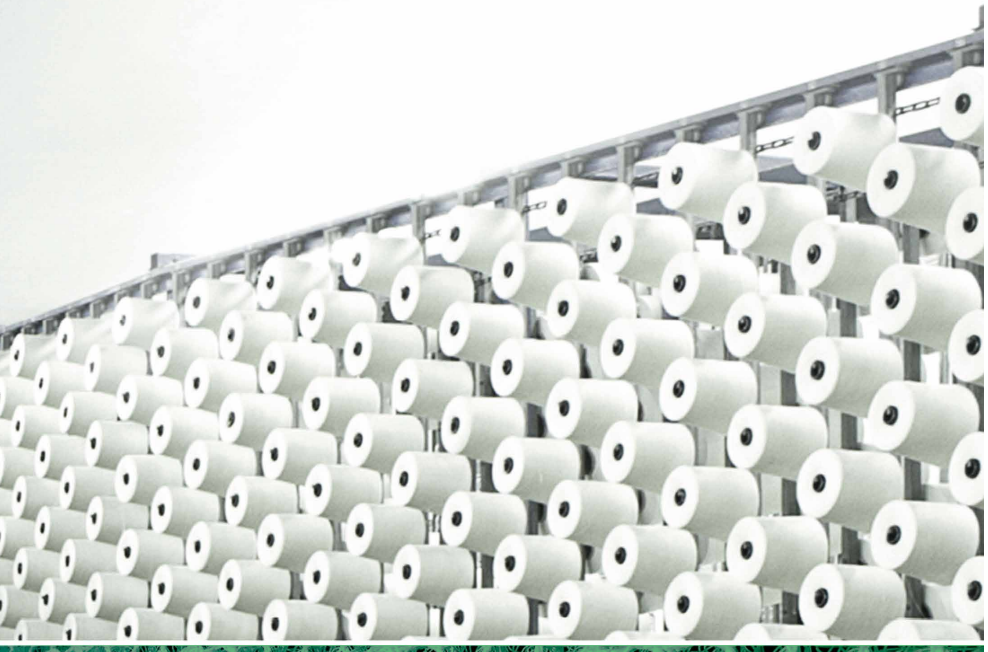
The sleeping bag avoids the usual mix of materials and thus also problems with disposal. It holds together through a series of innovative double layers and offers versatility and comfort. The SeaCell™ fibers are well suited as a functional material for sleeping bags thanks to their properties: they are breathable, absorb moisture 50 times faster than cotton, insulate and have a thermoregulatory effect. The design of the diaper has also been adapted in terms of mono-materiality. Instead of Velcro, the nappy is fastened with a tape, which is knotted on the back, for example. At the same time the size of the nappy can be adjusted by knotting the tape.

Sensu sleeping bag and Sumo reusable diaper made with SeaCell™

The DITF enabled the development and production of suitable textiles such as yarn, fabric or nonwoven as part of the master's thesis. The starting product was SeaCell™ fibers in flake form. Master student Luisa Kahlfeldt received the Swiss James Dyson Award, the Special Vitra Award and a BG Engineering Award for the diaper developed as part of her master's thesis. In addition, the material received an award as one of the ten most innovative in 2019.







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 Industry 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

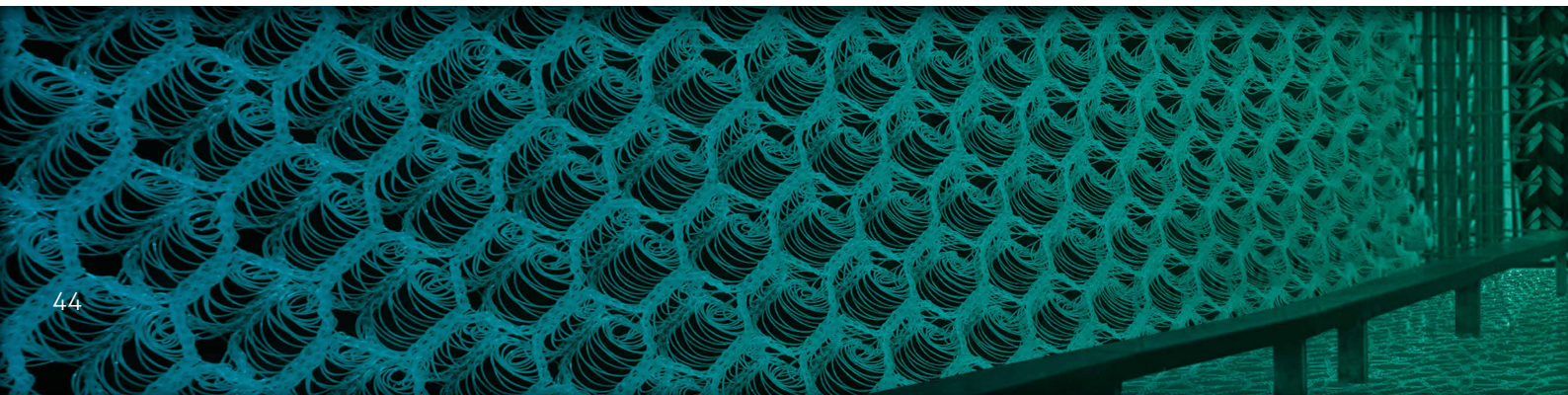
Production technologies

"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 the DITF research projects encompass production technologies, which make up the most substantial portion of applied research.

Along the entire textile value chain

New process techniques and process technologies can never be developed in isolation. For example, when developing a new yarn, the question arises as to how the yarn behaves in terms of surface, finishing and end product. Only with differentiation in the end product will a new yarn become established on the market.

The DITF researches along the entire textile value chain. They use the know-how of experienced specialists in the individual process stages to achieve the optimum result for the customer. The focus is on the holistic approach to research and development that takes into account all areas such as technical, textile technological and economic aspects. Therefore, the DITF employs experts from very different disciplines, such as textile technology, mechanical engineering, process engineering, chemistry, physics, biology, cybernetics, computer science or economics.



In keeping pace with industry-related processes

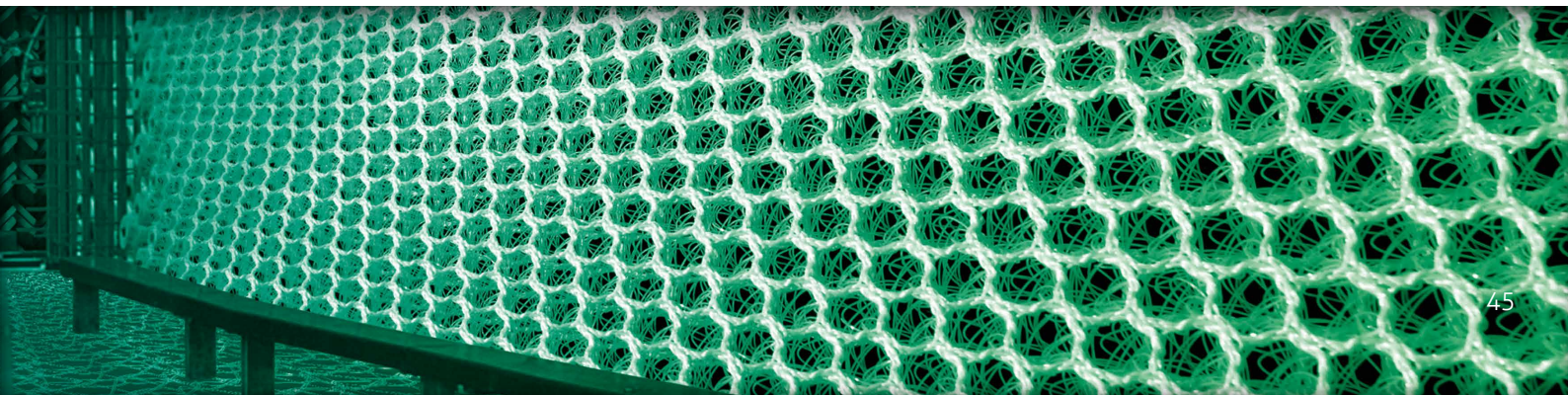
Applied research and development are only possible for processes that are close to the industry. The DITF have a research and production space of around 25,000 m², which permits a swift response to new production technologies and customer needs. We were able to equip industry machines with technology 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.

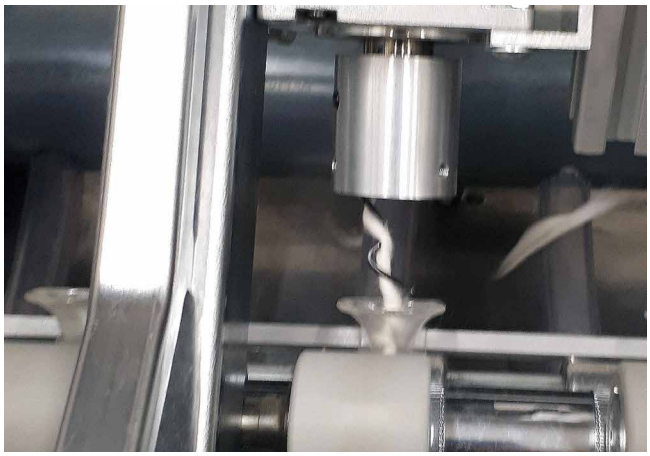
Textile machines of the future are multifunctional, easy to operate, and connected. The flexibility of machines becomes more critical to increase production. Machines with flexible batch sizes require flexible approaches that can be adjusted swiftly and therefore permit a more significant application. 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.

Industry 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.



Twist offset of rovings for fiber material with a higher proportion of short fibers

The raw cotton costs in the staple fiber spinning mill amount to more than 40 % of the yarn production costs. The blend ratio of recycled staple fibers in yarn production enables a reduction in material costs and the manufacture of sustainable and environmentally friendly products. However, increasing the proportion of short fibers is problematic. The loss of roving adhesion through the higher short fiber content had to be compensated by increasing the roving twist in order to avoid roving breaks and ensure a proper unwinding.



Twist offset element before the drafting system of a ring spinning machine

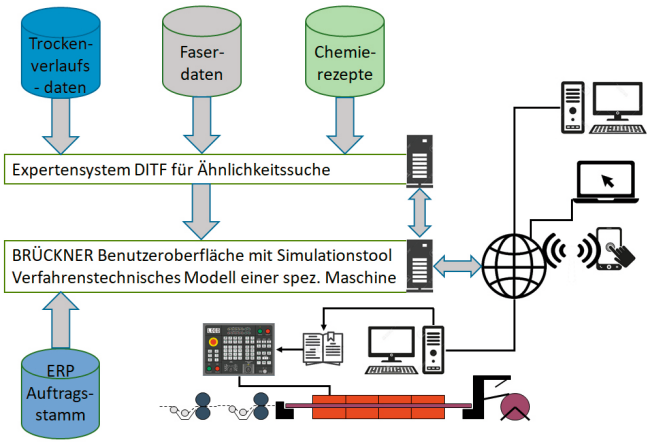
In the IGF project 19807 N, a device for the twist offset of rovings on ring spinning machines was developed for this problem. By this, the degree of the increase in twist during the processing of short fibers can be reduced with the same process reliability. The new device shifts the twist in such a way that on the one hand the roving is present at the drafting system inlet with considerably less twist (25 % - 75 %), and on the other hand there is sufficient twist in the section between roving bobbin and twisting element for undisturbed unwinding. This leads to a reduction of the distortion forces and an improvement of the distortion behavior.

As far as the quality requirements allow, a higher twist of the roving, which is dissolved before the drafting system, can increase the proportion of recycled fibers and thus short fibers in the yarn. Raw materials or recycled materials with a high required roving twist, which have not been considered so far, can thus be used to a greater extent.

AI: Self-learning expert system for the stenter frame

When drying and functionalizing textiles on the stenter frame, the question of the best process management in terms of energy or economy arises. Often users do not use the full potential of the machine. This is where DITF comes in with the ExPerTex project. Together with a sensor manufacturer and a manufacturer of stenter frames, an assistance system for textile finishers is being developed. This system proposes the most energy-efficient and sustainable process control for a specific application (textile, function, recipe, system configuration). Suitable methods of artificial intelligence (AI) process all available information about the materials and specific plant parameters as well as process data from novel sensors, so that this proposal is optimal.

At the DITF, the complex process knowledge is modelled and transferred into a knowledge-based system. This system maps the relationships between materials, binding, construction, application and drying behavior. Together with process analyses at the user's site and the integration of finishing and coating processes, a knowledge-based system is created that works with similar cases (case-based reasoning), heuristics and expert knowledge. For textile finishers, these methods serve to save time and costs by transferring person-bound experience knowledge into digitally processable structures. The applicability should be broad and apply to all relevant textile finishing processes where stenter frames are used.



TexPerTex data model – energetically and economically optimized process control in textile finishing

Fabrics made of oxide ceramic fibers (OxCeFi) for damage-tolerant ceramic components

Further progress was made at the DITF last year in the production and further processing of oxide ceramic fibers. In addition to the production of fibers based on alumina (OxCeFi A99) and mullite (OxCeFi M75), new fiber types made of zirconia-toughened alumina (OxCeFi AZ 96) were produced and processed in larger quantities.

In contrast to conventional ceramics, these materials, which consist of ceramic fibers in a ceramic matrix, are damage-tolerant and not brittle, which opens up completely new areas of application in high-temperature technology.

OxCeFi fabric burner nozzle

Fabric production from oxide ceramic fibers still poses a challenge, since damage-free processing is even more demanding than those of carbon fibers. In close cooperation between the institutes of the DITF, it has been possible to produce fabrics from all three of the above-mentioned fiber types and to process them into OCMC plates and demonstrators in cooperation with the company Pritzkow Spezialkeramik. With bending strength values of more than 400 MPa, outstanding properties were determined, which show that Denkendorf fibers can compete with the best commercial fibers.

Self-healing composites with filled hollow glass fibers

The formation of microcracks in the matrix of fiber composites causes great problems. If these structural defects propagate to a macroscopic crack, delamination between two fiber layers occurs. In an emergency, this leads to total failure of the corresponding components.

Self-healing glass fiber reinforced plastic thanks to storage depots made of hollow glass fibers

Microcracks in polymer matrices can be closed again by incorporated, curable monomer systems. In a current project, hollow glass fibers (GHF) were used as storage depots for curable monomers. A new system based on diols on the one hand and diisocyanates on the other hand was used, which cure to a polyurethane in the presence of a special tin catalyst. Contrary to the state of the art, the catalyst is not homogeneously distributed in the matrix, but is added to the diol component in small quantities. This brings clear advantages in terms of handling and costs.

A special filling technique for the GHF rovings or GHF fabrics and the use of a laser to melt the capillaries made it possible to produce GHF structures filled with reactive substances. These were processed together with normal glass fabrics to form multi-layer composites, cast in epoxy matrices and produced GRPs using the VAP and VARI processes. The GRPs and thus the hollow fibers were damaged by impact or bending stress, whereby the separately stored monomers diffuse into the crack by capillary forces. Both components react, solidify and thus prevent further propagation of the crack under renewed mechanical stress. In this way, about 50 % of the initial loss of strength is compensated.

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

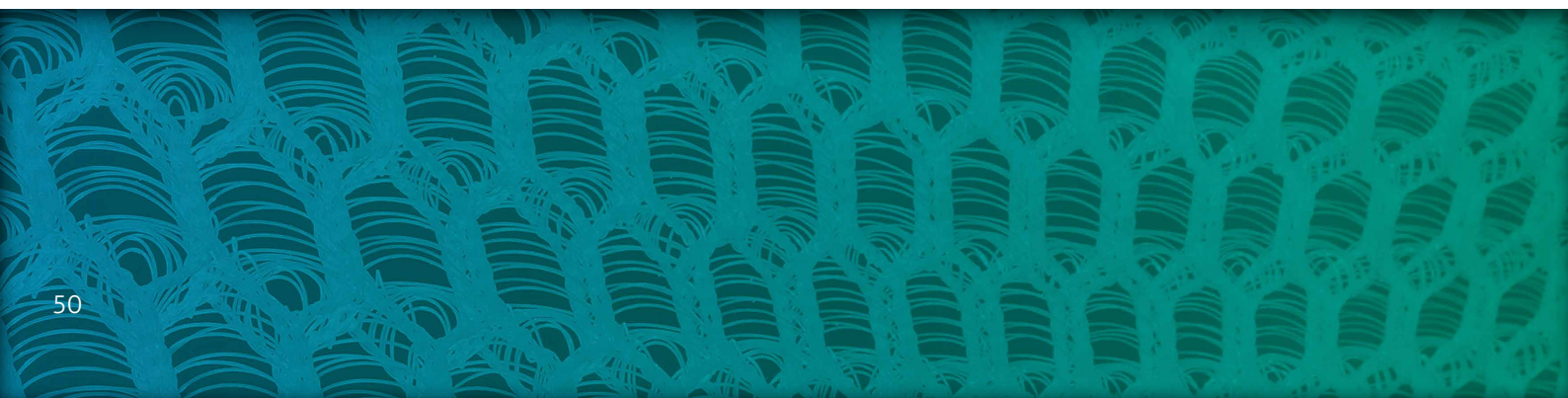
Continuous digital engineering and micro-factories

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

Big Data, Smart Data, and Artificial Intelligence (AI)

With a focus on the customers, it becomes increasingly vital to integrate their needs systematically at all stages of the production chain. The basis for this requires comprehensive data analyses, which turn the vast amounts of data, collected at the various stages of the production chain, into meaningful information. Smart Data – decision-relevant knowledge derived from the analysis and interpretation of vast amounts of data – combined with interactive and virtual product design environments, fitting of apparel, as well as the simulation of materials, wearer comfort, and lifestyle has the potential to make product development highly flexible but also to address market requirements concisely and efficiently.

Together with European partners, we work on new technologies for systematic customer integration at all stages of the supply chain. To make this happen, sales data but also customer needs and preferences can be used to generate data-based services. Big Data and AI provide new approaches in that respect as well.



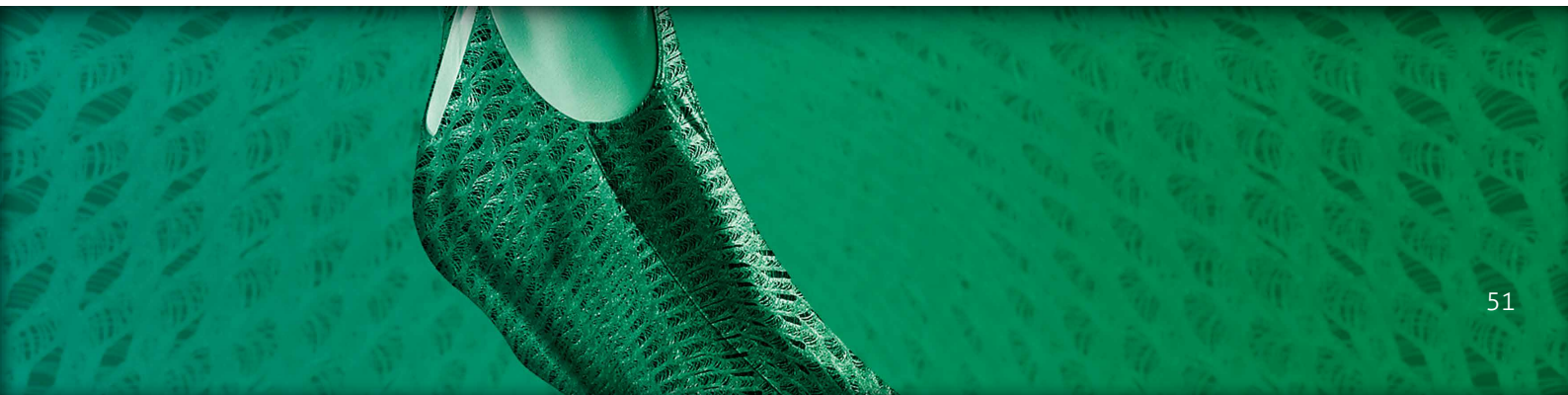
Interactive systems from production to trade

Production assistance systems can support employees with aggregated information and provide even more flexibility as well as robustness during processes while also contributing to individual and organizational learning. We also work with AI supported systems that permit the connection of information from machines and process data with staff knowledge and experience. Augmented Reality and Virtual Reality applications can help with implementation. These technologies, developed and tested during various projects at the DITF, offer new opportunities for information and interaction in the areas of production, job-related learning, or when used by the customers.

Sustainability and competitiveness

All environmental, economic, and social aspects of sustainability are gaining importance. Our expertise makes us part of the European initiative to create a broad network of companies in the textile industry with laboratories for innovation, service providers, and business consultancies. We want to provide alternatives to excess production and depreciation to regain production capacities in Europe, but also to bolster its competitiveness, and significantly decrease the ecological footprint of products. New value creation concepts like micro-factories appeal to the entire spectrum of the various dimensions of sustainability. In this context, the DITF institutes present works covering topics on traditional sustainability such as energy and resource efficiency. At the same time, we research materials made from renewables, the processing of high-performance natural fibers into threads, as well as the creation of cellulosic composites for practical applications. We study and analyze established as well as new materials, products, and processes in terms of sustainability based on a life cycle analysis but also the material flow cost calculation including diverse aspects of resource consumption and their costs.

First-class, technically-innovative, and sustainable products require the use of combined technology, innovative materials, and new processes, as well as appropriately qualified employees. Our expertise supports businesses in their area of specialization with needs-based, creative, and company-specific solutions at various levels of the entire value-added process, from creating the molecule to bringing a product to market.

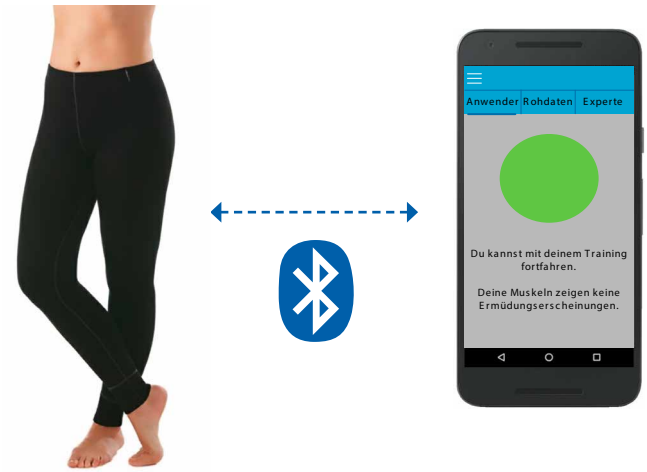


MoMuMy – sports pants for efficient training thanks to electromyography

The measurement of muscle action potentials with the help of electromyography (EMG) is a method of neurological diagnostics that has been established for decades. It allows the activity of a muscle to be recorded quantitatively. In the research project "Mobile system for real-time monitoring of muscle functions with the aid of electromyography – MoMuMy" in cooperation with the underwear manufacturer Comazo and the Hannover Medical School, a pair of sports pants are being developed to measure muscle activity.

Using textile electrodes, the desired muscle action potentials are measured specifically and in real time and muscle fatigue is determined with the aid of mathematical algorithms using an app from the company ATS Elektronik GmbH. With this biofeedback movement sequences can be optimized. The fields of application range from weight training and endurance sports to back training. For example, a marathon runner can recognize fatigue before the body registers it and thus adjust its running speed early on. Another economically-interesting field of application is the area of occupational safety and health protection. In many areas, accidents, illnesses, etc., which are due to physical overloading or incorrect strain, could be avoided.

In contrast to conventional electrodes, the textile dry electrodes integrated into the sports pants and developed at the DITF can be worn without skin irritation.



Sports trousers with real-time monitoring of muscle functions using electromyography

New business models in the digital age

In many cases, new business models promise more success in the development and introduction of new technologies, as in the context of Industry 4.0, than the mere innovation of products or processes. The potentials range from customer-specific solutions to supporting or substituting services to the reorientation and redesign of the entire value chain.

Workshop with industrial pilot partners on the FBD_BModel project in Prato, Italy

In the European research project "Fashion Big Data Business Model", new data-driven business models and IT solutions are developed and tested with 12 partners from research and industry. The focus is on the development and production of small, individualized batch sizes for clothing that meet both fashion and technical requirements and use the data required for this purpose to optimize the supply chain. Design and production can access huge amounts of data in an unexpected way, use them and thus offer the market what they want.

Example Digital Textile Microfactory

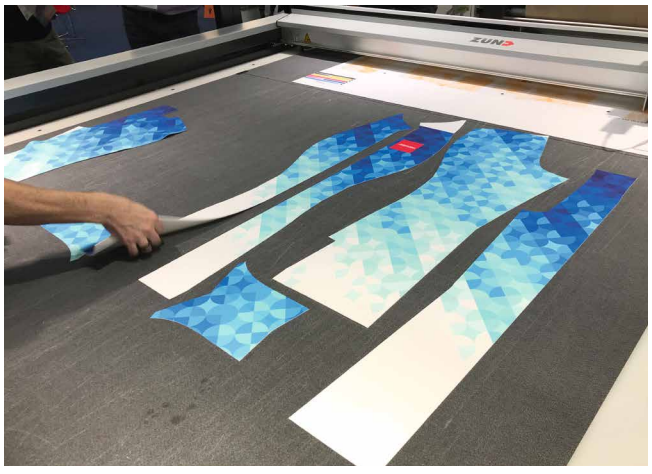
For a promising implementation of this data-driven approach, DITF-MR develops possible design and production scenarios, specifies them in archetypes and develops the necessary business models in business cases together with the participating companies. One example of an archetype is the Digital Textile Microfactory, which with its digital consistency and production of small batch sizes enables new business models in the areas of individualization, sample production, reordering and event-driven production.

Digital Textile Micro Factory @ DITF

In 2019, the Digital Textile Micro Factory was again presented at various trade fairs with great success. At the ISPO in Munich, the DITF demonstrated the production of a ski pant in cooperation with well-known partners. At Techtextil/Texprocess in Frankfurt, a total of three production lines were set up: a fashion line for the manufacture of individualized polo shirts, a production line for technical textiles with a focus on tracing and tracking and robot-assisted sorting, and a line which, starting from a virtual image of a shoe last, directly knits the shoe upper fabric in 3D.

Also 2020: important trade fair showcases scheduled

In 2020, the DITF will once again be represented with many trade fair showcases: Most notably at TVTecStyle Visions in Stuttgart, Europe's leading trade fair for textile finishing and promotion. There, the Digital Textile Micro Factory will present itself with the production of a polo shirt. At the ISPO in Munich, the largest trade fair in the sports business, the DITF, together with GORE TEX, Juki, Multiplot and Zünd, will be demonstrating on a total of 50 m^2 what a continuous process for the manufacture of individualized gloves can look like. The drupa in Düsseldorf, the world's leading trade fair in printing technologies, is adding the touchpoint textile to its range of trade fairs. Here, the DITF and international partners are planning to show the Digital Textile Micro Factory on approx. 200 m^2 in April 2021. Flags, bags and shirts will be produced with a focus on a current theme – several different products in one line, individualized on a daily basis.



Cut parts of an individualized ski pant at the ISPO 2019

Change for the fashion industry

These showcases show the diversity of possibilities of the Digital Textile Micro Factory: The production of a wide range of textile products in different showcases within a very short time. In addition, the digital production line demonstrates how technologies will change the individualization and production of batch size 1 and small batch sizes. Production structures can be strengthened at the location, nearshoring networks can be made more efficient and new business models based on digital technologies can be built up. New approaches link the data from 3D clothing simulation directly with virtual and augmented reality (VR/AR) and integrate them into digital textile printing, cutting, color management and ready-to-wear production.

Cutting an imitation leather bag on Texprocess 2019

The fashion industry is becoming more virtual, physical patterns can be visualized in the context of on-demand processes for customers and their integration into a micro factory can be shown via new possibilities of digitalization and direct customer involvement. The Micro Factory thus offers enormous potential for new business models at the location. The drivers are flexible and local production processes with low order volumes. The Digital Textile Micro Factory offers a fast route to tailor-made clothing while taking current trends and customer needs into account.

On the way to Industry 4.0: The DITF demonstrate the Micro Factory not only at trade fairs, but also at finalize the construction of the Micro Factory in 2020 at the DITF.

DITF BODIES

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

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

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