RESEARCH HIGHLIGHTS

DEUTSCHE INSTITUTE FÜR TEXTIL- UND FASERFORSCHUNG DENKENDORF

DITF REPORT

December 2021 – No. 3

# ADD International Conference

## From Stuttgart to the world: Successful hybrid event

On November 9 and 10, the Aachen-Dresden-Denkendorf International Textile Conference took place in Stuttgart. The DITF organized a digital event this year after the conference in 2020 had been cancelled due to Covid 19. 360 participants from 25 countries and four continents took the opportunity to be present at one of the most important European technical congresses. Ministerial Director Michael Kleiner delivered a message of greeting from Dr. Nicole Hoffmeister-Kraut, Minister of Economics, Labor and Tourism of Baden-Württemberg, who praised the successful program of the textile industry get-together. The conference is organized annually in alternation by the institutes ITM Dresden, DWI Aachen and DITF Denkendorf.

More than 60 lectures in plenary sessions and three parallel sessions were on the program. Experts from industry and research reported on research results and marketable textile innovations in the fields of high-performance fibers, fiber composites, medical textiles, functionalization and textile machinery construction. The topics of the conference focused on the upheavals that the textile industry has to cope with due to the digital transformation and the requirements of a sustainable circular economy. The possibilities for textile applications are vast. Whether mobility with fiber composites, architecture with modern building materials or smart textiles for everyday work, health or new extraordinary sports – there is hardly any area of life where high-tech textiles do not contribute to solving future challenges. The session "quo vadis textile machine concepts" showed that there is also still a lot of innovation potential in terms of methods and processes, and that it is being exploited. Under the motto "From idea to practice", the Forschungskuratorium Textil e. V. presented successful cooperation projects from the IGF-ZIM program in a separate transfer session, in which representatives from science and industry jointly developed and successfully implemented products and processes.

Chairs of the first day of the event (from left: Johannes Diebel, FKT, Jochen Gutmann, DTNW, Maike Rabe, Niederrhein University of Applied Sciences, Michael R. Buchmeiser, Götz T. Gresser, Michael Doser, Thomas Stegmaier, DITF. Not in the picture: Thomas Gries, ITA.

Speakers from this year's partner countries Portugal and Spain gave a comprehensive insight into the textile industry and research of both countries with lectures and discussion contributions.

The conference program was complemented by a virtual exhibition of companies and institutes as well as more than 100 scientific posters. Three of the poster presentations were awarded the Best Poster Award of the Aachen-Dresden-Denkendorf International Textile Conference 2021.

About 20 technicians and six interpreters were on duty to transmit the presentations and discussions around the world. The next ADD International Textile Conference will again be held as a face-to-face event as usual. On December 1 and 2, 2022, the DWI invites you to Aachen.

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# Biodegradable tree covers

## Development of a hybrid yarn from renewable raw materials

In afforestation, seedlings must be protected. So-called growth covers prevent game from feeding on the young plants and help to ensure that they are not prevented from growing by other (competing) plants. Previously used plastic and metal sheaths are often not removed in time and pollute the environment. The DITF have developed a biodegradable yarn for growth covers from renewable raw materials.

Reforestation is not only necessary after storms and fires. In general, the forest must be prepared for climate change through mixed stands and rare tree species. Growth envelopes are an important component of forest management in the early years. Covers available on the market must be removed and collected after three to five years. This is often not done due to lack of personnel, or is no longer possible due to overgrowth, or because the cover has grown into the tree. As a result, numerous growth covers remain in German forests every year until they rust or are shredded into environmentally harmful plastic components by external influences. Although currently available variants made of bioplastics are based on renewable raw materials, they are not biodegradable, decompose already during the use phase and pollute nature with small and microplastics.

The company Buck GmbH & Co. KG therefore commissioned the DITF to develop a yarn from renewable raw materials that is also biodegradable. This yarn should be able to be processed into a tube using a knitting machine and then consolidated into a stiff but at the same time pliable tube.

Renewable natural fibers and polylactide (PLA), which the Trevira company provided free of charge for the research, were used as starting materials for the development of a hybrid yarn. PLA consists of chemically bonded lactic acid molecules and is currently the only biodegradable thermoplastic available on an industrial scale. Particular attention was paid to a high purity of PLA to avoid environmental damage from plasticizers or other ingredients.

*Stephan Baz (Head of Staple Fiber Technologies) with the environmentally friendly tree cover in original size and as a demonstrator on a red maple. In the foreground: hybrid yarn variants made from flax or cotton.*

Flax fibers were initially used as renewable natural fibers. In several successive processes of spinning preparation, they were opened with the PLA staple fibers, mixed and processed into a fiber sliver. Subsequently, preliminary investigations were carried out to determine a suitable yarn structure for the biobased hybrid yarn. A simple, widely used spinning process was sought that would ensure rapid implementation on an industrial scale. Spinning trials were carried out on a rotor spinning machine, on the roving frame, a process upstream of ring spinning, and on a wrap-around spinning tester developed at the DITF. Finally, roving production by means of a roving frame was selected, since this process produces a voluminous as well as at the same time strong hybrid yarn with sufficiently flexible setting parameters and, moreover, is widely used by many spinning mills. The hybrid yarn was then processed into a knitted fabric at Buck GmbH & Co. KG to produce a knitted fabric from which a beam cover was made.

For material and economic reasons, the flax fibers were replaced by cotton fibers to optimize the hybrid yarn. The cotton fiber is more flexible across the longitudinal fiber axis than the flax fiber. As a result, it is more flexible in the knitted fabric and in the subsequent application as a tree cover in relation to forces acting from outside, such as animals or wind. Cotton fibers are available in cotton spinning mills compared to flax fibers, increasing the number of potential suppliers for the hybrid yarn.

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*Tree cover made of yarn developed at the DITF in use*

# Planer cutters in extremely lightweight design

## Virtual product development enables 50 % lighter CFRP cutter generation


*Demonstrator: Peripheral milling cutter for woodworking with maximum possible material replacement using high-performance carbon fibers (CFRP)*

The milling cutter represents the most important component in woodworking. Customers' requirements in terms of achievable surface quality with higher productivity are constantly increasing. Peripheral milling cutter known as planer head available on the market are made of aluminum and have largely exhausted their lightweight potential. Lighter and more rigid tools could, as a result of higher speeds and optimization of vibration behavior, enable higher surface qualities and production speeds on the one hand and save energy on the other. This should provide a boost to innovation for the German woodworking industry and tool manufacturers.

To this end, the IGF project "Development of highly dynamically loadable, lightweight basic tool bodies for wood and wood-based material processing (20128N1+2)" was to utilize the know-how of the DITF on FRP manufacturing technologies, load optmized design with high performance fibers and virtual product development using numerical Simulation (FEM) in collaboration with the Institute for Machine Tools (IfW), University of Stuttgart.

Based on the analyzed loads of an 8 kg planer head (Ø 125 mm, length 135 mm) and a current maximum speed of 12,000 rpm, the first calculations showed the possibilities of mass reduction by a proportional material replacement using carbon fiber composite (CFRP) materials. However, this did not exploit the strength and stiffness potential of the high-performance carbon fiber. Detached from the common tool concept, numerous, completely different design forms were simulatively evaluated under the aspect of optimal utilization of the fiber properties. The result is a fundamentally new modular design concept that makes it possible to save more than 50 % of the mass of face peripheral milling cutters with high-performance carbon fibers and thus to enter new operating speed regions. Numerical simulations show that with this extremely lightweight design by the DITF (patent pending), more than 50 % higher operating speeds should be possible without any problems. Manufacturing methods were selected for the individual CFRP components, initial prototypes were produced and their quality analyzed using µCT. The CFRP components were machined, assembled and equipped with cutting edges at Leitz GmbH & Co. KG. Initial milling tests conducted by Leitz with the demonstrator on MDF panels at 12,000 rpm showed that thewood surface quality achieved by the demonstrator corresponds to that produced using conventional planing tools.

The extreme lightweight concept developed leads to maximum weight savings with the greatest possible rigidity thanks to a completely new modular design principle with optimal load distribution of the carbon fibers. The economical and reliable production of the CFRP individual components with the required accuracy and corresponding tolerances is a major challenge for suitablility for series production and requires further research activity. The demonstrator enables initial functional tests and an evaluation of the possible performance and application potential. In addition, the conceptual design needs to be further optimized and specifically investigated for max. speed, damage tolerance, long-term, failure behavior and functional integration. The new DITF extreme lightweight construction with the modular design concept is also transferable to other tools and applications, which will be investigated in further research projects.

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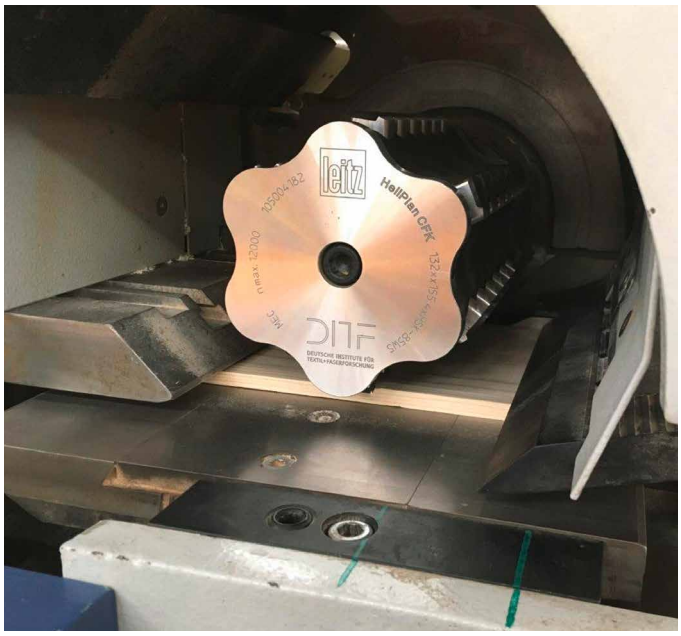


*Peripheral milling cutter for woodworking in operation*
*(© for all images on this page: Leitz GmbH & Co. KG)*

# Flexible scoliosis orthosis

## Development of a scoliosis orthosis based on elastic textiles

Scoliosis is a spinal condition in which the spine and torso curves three-dimensionally, mainly as people grow. It usually develops during puberty and increases especially with increased body growth. Even mild scoliosis causes pain and movement restrictions. For generations, scoliosis patients have been pressed into tight, stiffening and painful corsets to straighten their bodies. Alternatively, there is the surgical procedure, which is not without risk. Valuable time is often lost due to far-reaching treatment decisions that are binding for a long-term and irreversible form of therapy. In most cases, the increasing progression of scoliosis can be halted with an early start of therapy.

In an R&D project, the DITF and its project partner DCC Mühltal developed a novel dynamic scoliosis orthosis for the treatment of progressive idiopathic scoliosis. The basis for this are flexible textile structures. The primary aim is to halt the deterioration of scoliosis during growth spurts by guiding physiological movement mechanisms and promoting the perception of movement sequences, thereby preventing severe deformities. For this purpose, special scoliosis-specific mesh structures were developed to generate defined tensile forces. The design and pattern development of the garments for axial alignment of the scoliotic, three-dimensionally curved body was supported by finite element simulations. The models and procedures developed at the DITF enable the simulation of the virtual fitting and the textile properties in interaction with the body. Stance and gait analyses proved that the developed scoliosis orthosis can achieve body straightening as well as normalization of body balance. The light, elastic scoliosis orthosis has a much gentler effect on the patient than previous corsets. In addition, it extends the range of motion and supports biomechanics. Wearing the orthosis inconspicuously under everyday clothing also increases acceptance, especially among adolescents.

Side and front view of the orthosis with integrated function module

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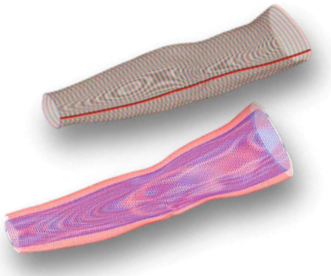
# 3D knitting as an additive manufacturing process

## Start of the AiF project AddKnit – development of a process model

Whether compression textiles, seat covers for wheelchairs or shoe uppers - the market is dictating increasingly complex combinations of materials, shapes and designs. The demands placed on the technical textiles used are therefore becoming increasingly sophisticated, while at the same time batch sizes are getting smaller and smaller. In order to be able to continue producing economically and at acceptable market prices in the future, companies are increasingly under pressure to automate product development accordingly. 3D flat-knitted products can be manufactured in a wide range of variants thanks to the flexibility and performance of the machines. However, the path from model to product is characterized by a low level of automation and many iterations between product design and prototype production.

This problem is addressed within the framework of the AiF project AddKnit, which started on 01.09.2021. The aim of the project is to develop recommended actions and software modules for the production of 3D-knitted technical textiles. Based on a 3D scan or CAD design, a digital twin of the knitted product is to be generated algorithmically. This can be transferred into a parameter set for direct production on a flat knitting machine. The product type, the material used and the machine configuration are to be taken into account. This process model is intended to make 3D knitting technology a textile equivalent of 3D printing in terms of applicability and flexibility.

The project results will primarily benefit manufacturers of technical textiles, but also mechanical engineering companies and suppliers of corresponding software solutions. As a result, development times can be significantly reduced, machines and their components can be optimized for specific products, and new business concepts can be created. Interested companies can each currently participate in the project-accompanying committee.



Example of 3D scanned and scanned arm geometry (top; bottom – red) with the digital twin of a compression stocking (bottom – blue).

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# Textiles in the Exterior – The Car of Tomorrow

## Integration of application-specific functional elements in fabrics

Electric micro-vehicles are now part of the urban landscape. Due to their low weight, they enable a reduction in particulate emissions as well as an increase in driving range. They offer little and small installation space, so that the integration of usual functionalities, such as heating, lighting, etc., is only possible thanks to compact solutions. Textiles are ideal for this purpose: they are light, inexpensive, flexible, resilient and can be functionalized in many ways.

Textile covered car door with functional fabric

To illustrate the principle of functionalization, the DITF, together with students from Reutlingen University and Fraunhofer IAO, produced a functionalized textile vehicle door for a Renault Twizy. A robust, waterproof and breathable fabric was selected as the basic textile and functionalized. The integration of a textile lighting into the basic textile served to indicate the battery charge status of the vehicle and could additionally be used as lighting. Thanks to a printed capacitive textile pressure sensor, the display could be acknowledged or the lighting activated or turned off. Due to shielding, the pressure sensor can only be switched from the inside of the vehicle door and is thus protected from the influence of external persons and elements.

Miniaturized electronics combined with suitable programming of the integrated microcontroller ensure reliable control of the various functional elements. Parallel to the textile functionalization, a cutting pattern including a fastening concept was created so that the functionalized textile can be perfectly adapted to the door geometry and fitted. The functional samples were successfully tested in road tests at the DITF and the equipment of micro-vehicles with functionalized textiles was demonstrated. Textile technology offers numerous possibilities to meet application-specific requirements through the selection of adapted polymer and yarn properties as well as the production of textile structures combined with the integration of functional elements.

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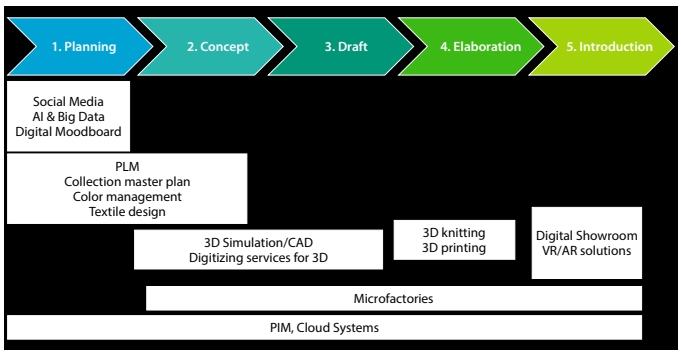
# Digital collection development

## Individual potential analyses with the help of material flow cost accounting

The digital transformation continues to advance in the apparel industry and offers numerous potentials – from virtual product development to the direct involvement of customers and retailers. However, for SMEs in the industry in particular, these opportunities are also faced with many challenges: Individualization, flexibilization and sustainability are just a few that need to be overcome. Ever-increasing competition and cost pressure are also not making the transition to digitization any easier. The DITF is conducting research in this area with a focus on the collection development and production process. As part of the AiF research project "Digital Collection Development", it was shown how apparel companies can tackle these challenges with manageable effort and realize digitization with the help of a successive transformation.

The procedure was tested on the basis of case studies from various members of the project advisory committee who are active in different product groups (accessories, sportswear, workwear and children's clothing). Here, individual potential analyses were carried out taking into account a parameterizable model for calculating material, personnel and environmental costs (MFCA – Material Flow Cost Accounting). Individual phases along the collection development process and existing tools were analyzed, and suitable digitization scenarios were defined and coupled with the potential of the case studies. The results help to evaluate the costs associated with digitization, the time required, but also the necessary qualification requirements, and thus form the basis for enabling SMEs in the apparel industry to digitize with the help of a step-by-step implementation.




Analysis of the digitization potential of individual phases along the collection development process with existing tools

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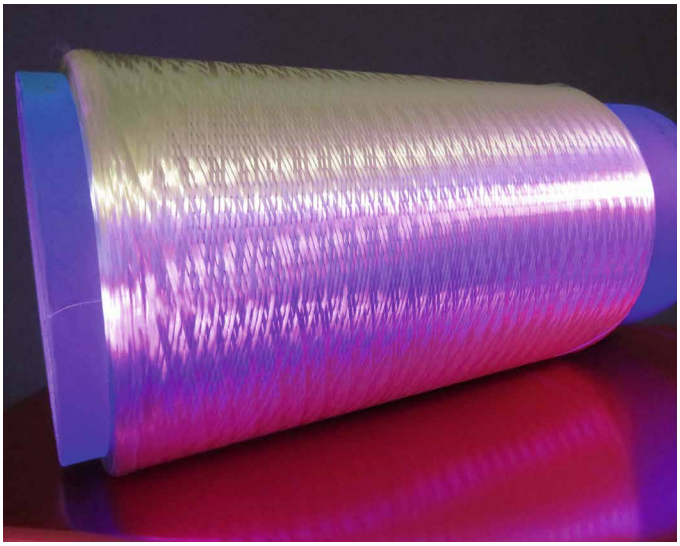
# Cellulose fibers against climate change

## An economical concept for capturing $CO_2$ from the air

Protecting the global climate is an undertaking that presents both industry and society with a major task. It will not be possible to achieve the climate targets simply by limiting global emissions through carbon dioxide ($CO_2$) savings. This is because there will continue to be unavoidable $CO_2$ emissions that will nevertheless have to be compensated. Ways out of this predicament can be measures such as reforestation, carbon sequestration in the soil or even the active capture of $CO_2$ from the air. Such so-called "direct air capture technologies" are already being tested from various approaches on a research scale or in pilot plants. In one of these processes, special filters are used to remove $CO_2$ from the atmosphere. As part of a research project, the DITF is developing textile materials for separating $CO_2$ from the air. $CO_2$ can be fixed in this way over the long term and thus permanently removed from the climate cycle, or it can be used as a raw material for the production of $CO_2$-neutral hydrocarbons.

While several companies are already competing internationally to find the best technology for extracting $CO_2$ from the air in large quantities and profitably, the economics still stand in the way of the really big breakthrough: The small proportion of $CO_2$ in the atmosphere (0.04 %) requires enormous amounts of air to be pumped through the filters in order to filter out a significant proportion of $CO_2$. Separating the absorbed carbon dioxide from the filters in turn requires larger amounts of thermal energy. Economic operation is not possible under the present conditions. In the further development of $CO_2$ separation from the air, it will therefore be necessary to turn several screws in order to increase the technological efficiency of the process and at the same time minimize energy consumption.



Cellulosefasern der DITF als Filtermaterial

### Self-sufficient air filter for $CO_2$ separation

A joint research project of the Center for Solar Energy and Hydrogen Research Baden-Württemberg, the DITF Denkendorf, the Institute for Energy and Environmental Research Heidelberg and Mercedes-Benz AG Sindelfingen aims to realize an improved, highly efficient $CO_2$ separation from air using tissue-fixed amines. The process is to be implemented in a demonstrator that can be operated autonomously: resource consumption is to be based purely on renewable electricity and waste heat, covered by solar energy or heat pumps. The special design of the air filter will enable continuous operation of the plant, unlike already established processes. This improves the upscalability to industrial scales.

Within this four-year joint research project, the DITF is contributing its many years of expertise in the development of cellulose-based fiber materials. They will be used as filter media in the demonstrator. Based on the results of a previous research project, in which a screening of possible processes for $CO_2$ removal from the air and the sorbent materials used for this purpose had already been carried out, cellulose-based fiber materials were chosen for the current research project.

### Optimized cellulose fibers from Denkendorf

Under the direction of Dr. Frank Hermanutz, the fibers for the filters are spun out in the Biopolymer Materials Competence Center and chemically modified so that they couple amines to their surface. New spinning processes are being developed and optimized for this purpose in the DITF pilot plants. The amines ensure the temporary binding of the $CO_2$ to the filter material. The advantage of using fiber-based cellulose lies in the open, air-permeable structure of fiber-based materials. Not only do they allow a high air throughput, but they also have a large specific surface area, which is advantageous for binding the largest possible volumes of $CO_2$. The aim of chemical modification of cellulose will be to optimize both the fiber itself and the binding of the amines in such a way that the adsorption capacity for $CO_2$ is exploited to the full.

A completely new process engineering concept is being pursued in the design of the filter: A static filter is not used, as is usually the case, which has to be baked out after the amino groups have been fully loaded with $CO_2$. Instead, the filtration process is integrated into a continuously operating process that permits continuous and energy-saving operation. If the system is connected to existing air streams such as building air conditioning systems or exhaust air, there is no need to use energy-intensive fans.

The filter is designed as a special belt apparatus in which the cellulose fibers are processed into endless belts in the form of nonwovens. These belts, like a conveyor belt, run on roller conveyors through the incoming air stream, where they bind the $CO_2$. The belts are then heated in three temperature zones in a spatially separated desorption area. There, water and $CO_2$ separate from the amino groups. The continuous process, which is made possible by the circulating nonwoven belts, permits cost-saving and low-maintenance process control. In addition to the recovery of $CO_2$, the separate removal of water will also provide a synergetic effect of high value: Since the plant is already designed for energy self-sufficient operation, it is in principle possible to operate it in areas with poor infrastructure and water scarcity. Water production can then represent a not inconsiderable added value. The design as a belt device makes it easier to

scale up the process to very high performance classes, since this requires above all an easy-to-implement increase in the belt length.

The collaborative research project "CORA" is funded by the German Federal Ministry of Education and Research (BMBF) under the supervision of the project management organization Jülich. The consortium leader is the Center for Solar Energy and Hydrogen Research (ZSW), Stuttgart.

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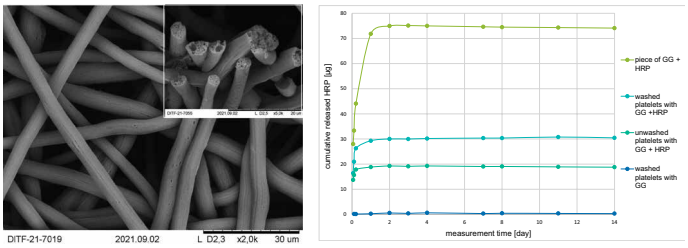
# DGBM – Poster Award

## Porous 3D-printed structures for drug-releasing systems

Once a year, the German Society for Biomaterials (DGBM) invites to its annual meeting, where members discuss their current research projects in the field of biomaterials for medical applications. Already in 2020, the conference was to take place in Stuttgart, but had to be postponed due to the pandemic. This year, conference chair Prof. Dr. Michael Doser was at least able to invite to an online meeting on October 7 and 8. Together with colleagues from the Universities of Stuttgart and Tübingen, Reutlingen University of Applied Sciences and the NMI, Michael Doser had put together a diverse program: this included the topics of biobased materials, infection control, regenerative medicine, biofabrication and cell-material interaction. Well-known scientists introduced the topics in keynotes: among others, Tony Mikos from Houston reported on the possibilities of 3D printing to "biomimetically" adapt cell carriers for regenerative medicine.

The three contributions with which the DITF participated in the conference matched this. In his presentation, Carsten Linti explained the DITF's new approach of combining 3D printing with melt electrospinning in one facility. In regenerative medicine in particular, this makes it possible to combine structures of varying density and porosity and thus optimally adapt them to the natural structures in the tissue. 2 medical technology students, Manuela Schön and Carla Siegle, were able to show in their posters that it is also possible to add microporosity to the 3D-printed structures. Active ingredients could be stored in these pores in hydrogels, which are then later released in a targeted manner to control the healing processes. Carla Siegle received a poster prize from the DGBM for her contribution.




Electrospun porous microfibers of PA6/PEO (left) and time-dependent HRP release from loaded pores (right).

# Vacuum embedding device for microscopic preparation

The acquisition of a Struers CitoVac vacuum embedding device made possible by the "Verein der Förderer der DITF", opens up new possibilities for the microscopic preparation of textile materials at the DITF. With the help of the embedding device, samples with large surface areas or porous structures can be embedded bubble-free in epoxy or acrylic resins.

This type of pre-preparation is particularly suitable for the examination of composites with open porosity or of voluminous textiles. Vacuum embedding enables complete impregnation of such materials. This prevents air inclusions, which can impair both the section preparation and the microscopic evaluation. In this respect, the CitoVac vacuum embedding device represents a valuable asset for the optical analysis of textile-based materials.


*New at the DITF: Struers CitoVac vacuum embedding device*

# Ceramic Forum International

On the occasion of the 100th anniversary of the DITF, a detailed report on 100 years of textile and fiber research as well as on 30 years of ceramic fiber research in Denkendorf has been published in the current issue "ceramic forum international" (Berichte der Deutschen Keramischen Gesellschaft, 5-6, 2021; S61 ff). The journal is freely available:

https://www.cfi.de/magazine/current-issue.

# Denkendorf Future Workshop

## Food for innovations


Today, innovations are more important than ever. Against the backdrop of globalization and a constantly changing market environment, they determine the success of a company. A flexible response to customer requirements is demanded at ever shorter intervals. In this context, a basic dilemma of a successful innovation process has been well known for a long time and Georg Christoph Lichtenberg already formulated it in the 18th century as follows: "It is not said that it will become better if it becomes different. But if it is to become better, it must become different."
A structured innovation process is necessary to generate new marketable and implementable ideas. The Denkendorf Future Workshop, now in its 15th year, has been very successful in providing support for this. It provides targeted and systematic support for idea generation. In a typically one-day workshop, which is prepared in close cooperation with the customer, ideas and solutions are developed in a structured and open manner. The majority of the workshop members are employees of the customer and are supplemented by DITF scientists according to the specific questions. The workshop is moderated by the DITF and starts with a keynote speech – tailored to the focus of the company. Afterwards, a list of ideas that can be implemented is compiled and evaluated using well-known creativity techniques. The Denkendorf Future Workshop can also provide support in the implementation of the ideas.

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# innBW Colloquium on the AI EscapeROOM

In October, the DITF presented the AI EscapeROOM at the monthly colloquium of the Innovation Alliance Baden-Württemberg (innBW). More than 70 scientists from innBW took advantage of the offer to playfully get to know the AI EscapeROOM in a digital meeting.
Dr. Heiko Matheis, AI trainer at the DITF, led the event and, after a short introduction to AI, provided the necessary explanations for the online game, which was then mastered successfully and with great enthusiasm in parallel breakout sessions in small groups. In the digital implementation of the AI-EscapeROOMS, the players were faced with the task of helping to build an AI-supported weather control center.
Like the on-site KI-EscapeROOM in Denkendorf, the online offering is aimed at small and medium-sized industrial companies. In the KI-EscapeROOM, they can experience the potential of artificial intelligence (AI) in a playful way and take away valuable impulses and ideas for their own work. At the end of the online game, there is not only the control center, to which the real AI EscapeROOM is linked, but the participants know what artificial intelligence can do – and what it cannot do. The players know both different tasks that AI can solve and different algorithms that AI uses.
The AI EscapeROOM is an offer of the Mittelstand 4.0 Kompetenzzentrum *Textil vernetzt* and was jointly implemented by the DITF and Hahn-Schickard. If you would like to try out the online game or the real AI escape room, please contact Dr. Heiko Matheis.

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**Exhibitions & Events**

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| **January 27** | Forum Functionalization – DITF Denkendorf in cooperation with AFBW and Hohenstein |
| **February 16 – 17** | 9th Composite Simulation Congress – DITF booth in foyer exhibition |
| **March 02 – 03** | 10th User Forum SMART TEXTILES – TITV e.V. in cooperation with DITF and FKT e.V. |
| **March 08 – 10** | JEC World 2022, Paris – DITF at the CU Joint booth |
| **March 31 – April 02** | TV TecStyle Visions, Messe Stuttgart, Round-Table Sustainability – Digital Micro Factory |
| **April 28** | Girls' and Boys' Day at DITF |
| **May 17 – 19** | Techtextil & Texprocess North America, Atlanta – DITF booth |
| **June 21 – 24** | Techtextil, Frankfurt a. M. – DITF booth |

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