DESIGN DRIVEN VALUE CHAINS IN THE **WORLD** OF CELLULOSE **DWoC**

INTRODUCTION

This brochure was made for documenting and visualizing the process and results of the first phase of **DWoC.** The content is based on the presentations and exhibition in **Designing Cellulose for the Future –seminar** in **Aalto ARTS 6.11.2014.** The main idea is to present all components of this multidisciplinary collaboration; scenario work, concept design, technology development and prototyping have been iterative processes and intertwined throughout the project. Hopefully DWoC findings and experiences inspire both academic and business societies, researchers, designers and of course students, future professionals, for further cellulose-related activities.

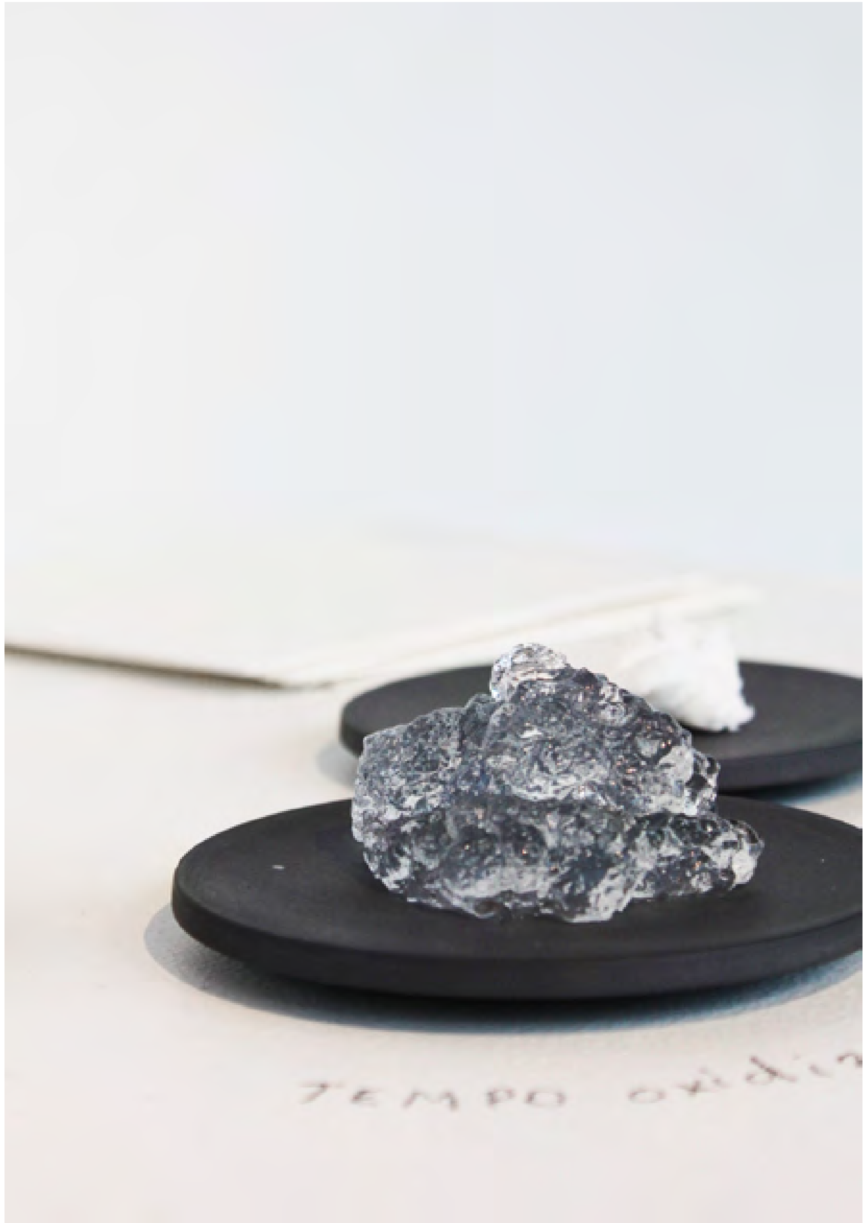
ABOUT DWOC

Wood cellulose has traditionally had a remarkable role in Finnish industry, although the productshave been mainly high volume and low added value products with no design involved. **DWoC**, **Design Driven Value Chains in the World of Cellulose**, is Tekes funded strategic opening aiming to make Finland as source of branded value-added cellulosic products and business concepts. DWoC aims to accelerate the transformation of the current large scale forest bioeconomy to a vivid ecosystem containing both large scale and small scale businesses.

Cellulose is one of the most abundant materials found in nature and is mainly produced by plants, but also by bacteria and algae. It is a structural component of plant cell walls, which is considered sustainable, renewable and multifunctional. Due to its abundance, biodegradability and chemical tunability, new methods of using cellulose have become an active research topic besides the traditional wood-based products. Combination of the recyclability to new end-use opportunities makes cellulose the potential supermaterial of the future.

DWoC was initially inspired by the **CHEMARTS** summer project carried out at **Aalto University 2012**, where the concepts of '**World of Cellulose**' and '**Luxurious Cellulose Finland**' were created by technology and art students. After that the idea was further developed with professors and scientists from **VTT** and **Aalto University**. DWoC concept is based on the combination of design thinking and design driven prototyping to a strong technology development competence. Combination of these strengths together is one of the key assets to raise the Finnish cellulose ecosystem to a globally competitive place in the future.

The first phase of the **DWoC** project (DWoC 1.0 period with **Tekes Strategic funding 1.6.2013 - 31.3.2015**) has successfully been carried out. The partners were **VTT**, **Aalto University** and **TUT**



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HOW DESIGN CAN CONTRIBUTE TO MATERIALS RESEARCH

Jukka Itälä MA thesis 2014,

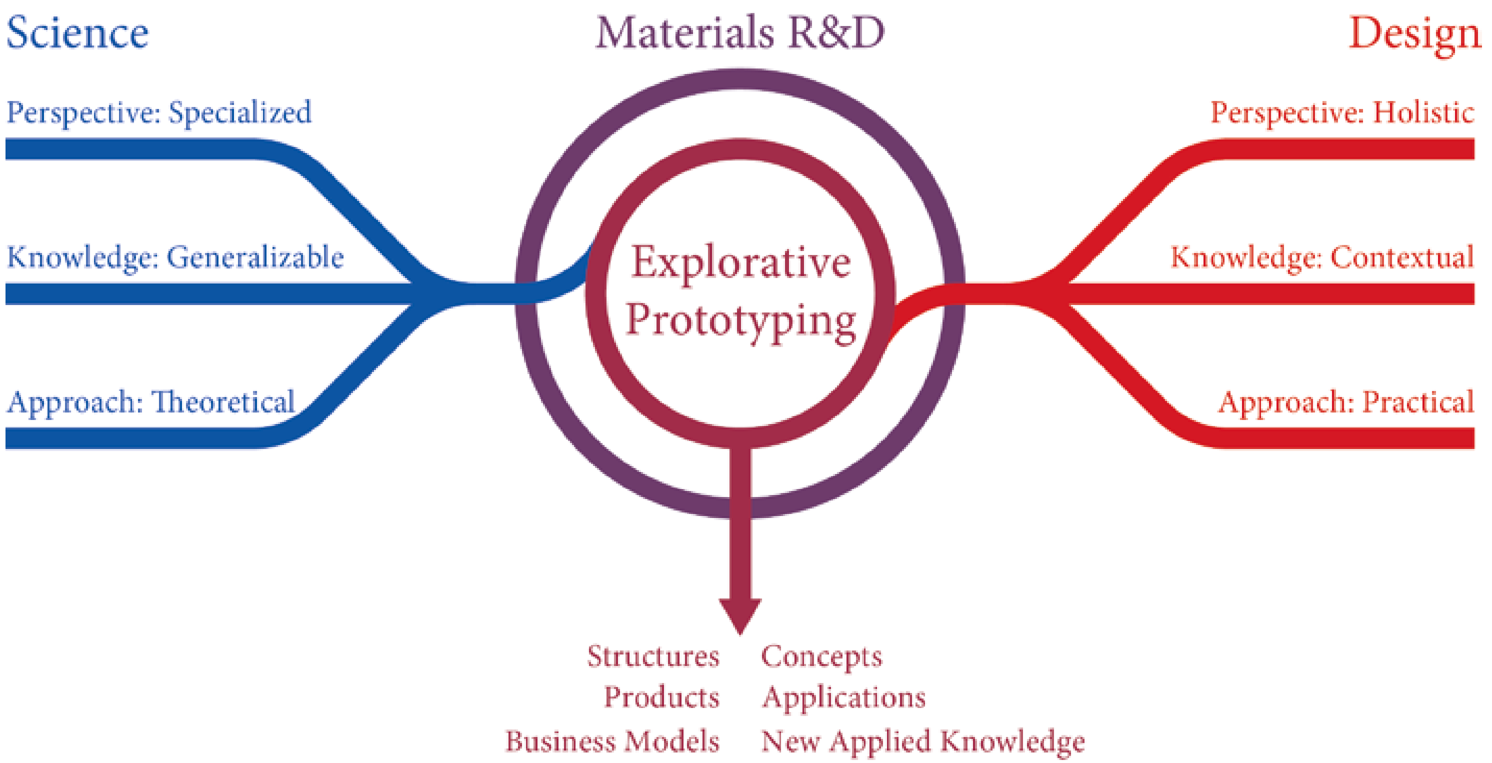
Industrial & Strategic Design, **Aalto University of arts design and architecture**

The thesis examines how design practice can contribute to the R&D of materials and their applications in collaboration with materials science. Examples from industry show that integrating design into materials R&D can be beneficial for innovation. Still this approach remains rare, especially in academia. A clear view on how the collaboration between design and materials science should function is also missing.

Scientists are experts in the technical side of materials development, but exploiting research for innovations requires a broader understanding of its meaningful application. Design essentially deals with broader themes related to the needs, uses and production of products and services. A designer is not only concerned with how a product is manufactured and made viable, but also with how it is made useful, usable, and desirable. Questions in materials development can also be multifaceted, relating for example to how materials could be used and further developed. The role of design is thus to look more comprehensively at materials, and evaluate not only their technical, but also perceptual (e.g. appearance, tactility) and associative qualities for understanding their potential uses. Additionally design tries to recognise current and future needs and requirements relevant for materials and their applications.

These questions can be approached with constructive design research executed for example through prototyping. Design uses various kinds of prototypes from digital models to mock-ups to pre-production products for searching not only solutions but also relevant problems. The approach of "explorative prototyping" is especially useful in the context of materials R&D, as it is used for understanding the behaviour and potential of materials, at best together with other professionals which facilitates also interdisciplinary collaboration.

The thesis highlights three case examples of explorative prototyping. The first case depicts how the production of different shapes and structures can be used for testing materials and their structural principles. The case describes the design and prototyping of a nacre-inspired biomimetic structure. In the second case design concepts, which depict potential future products, are inspected as explorative prototypes for "prototyping the future". The concepts are used to identify potential applications for nanomaterials, and thus also into which direction the materials could be developed towards. Finally, in the third case an already existing material technological invention is used as basis for a product concept idea, which is then prototyped. Here foam forming technology is studied for the production of moulded and dyed pulp-based acoustic elements. The prototyping provided new insights on the behavior and processing of foam formed pulp, which inspired even ideas for new business models around the technology.



By approaching problems comprehensively in order to understand the contextually relevant factors that affect the use of materials and their applications, design can advance the creation of novel applied knowledge. This can challenge and inspire materials scientists in their work, pushing collaborative research forward. The holistic and practical approach of design can effectively complement the specialized and theoretical approach of materials science, which can generate new possibilities for the development of material innovations.

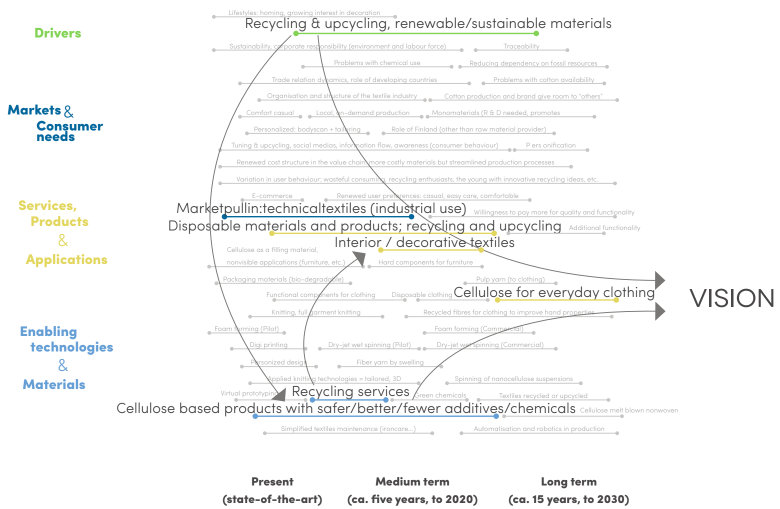
Road maps from following areas were selected

Health and wellbeing

Building and landscaping

Home and everyday life (Textiles)

The top priorities of the Home and everyday life (Textiles)



ROADMAPS

Introducing roadmaps

The aim of roadmapping is to describe the path from the present state towards the agreed vision. As a result, the pathway can be visualized in a roadmap illustration, which provides a summary of various factors on different levels at a glance. This helps to identify the correlations and interactions between factors and events, thus supporting the implementation of the roadmap.
When structuring a roadmap towards the DWoC vision in 2030, the contributing factors – drivers, markets and consumer needs, services, products and applications, and enabling technologies and materials – were studied. Three specific application areas of interest were identified and selected for more detailed analysis. Detailed roadmaps were thus created for:

- **home and everyday life (textiles)**
- **health and wellbeing**
- **building and landscaping.**

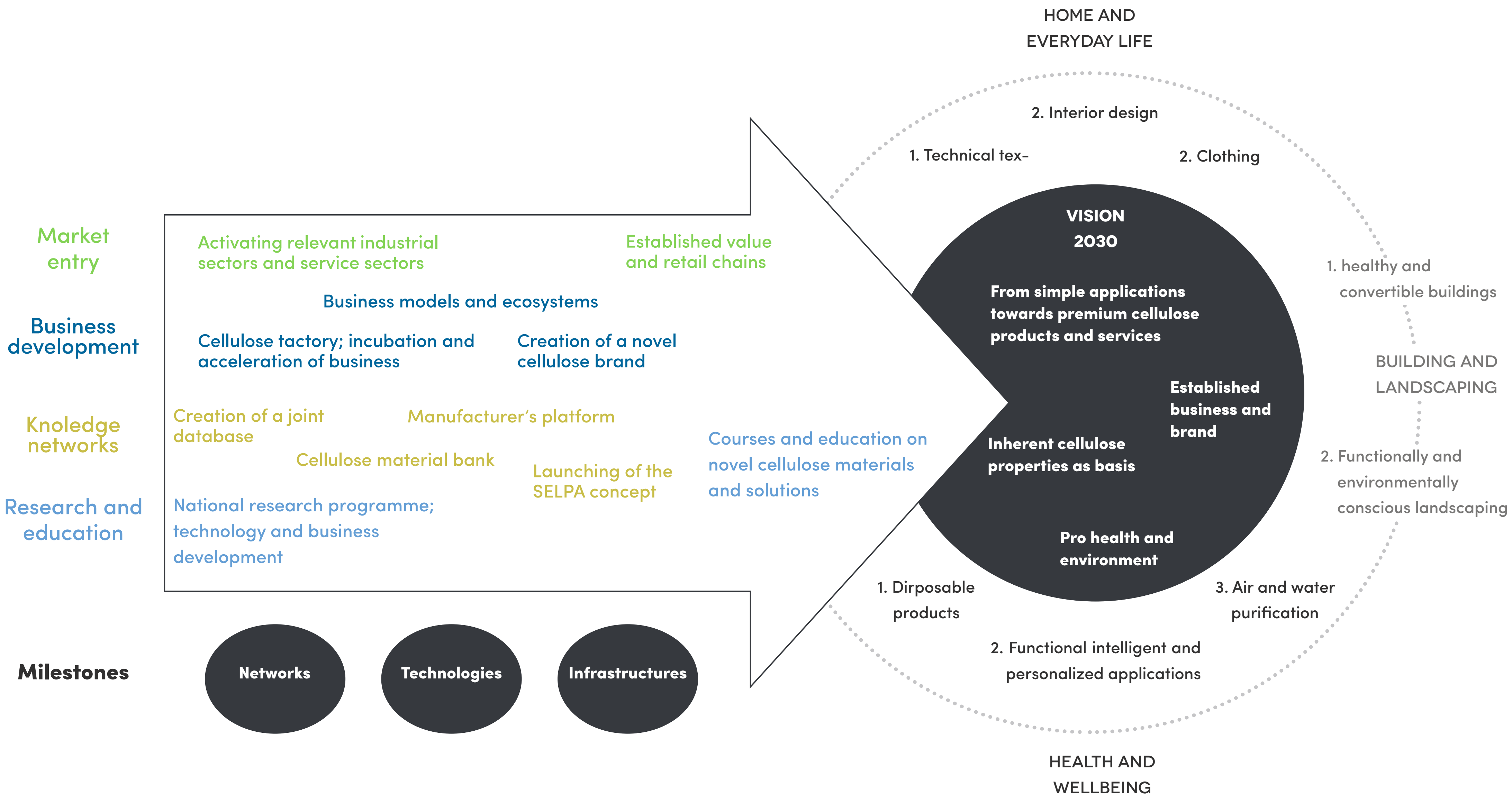
The contents for the three roadmaps were produced in workshops in which experts of the related areas took part. Supporting materials and knowledge were additionally obtained from literature and an expert survey of technology developers.

The use of roadmaps

A roadmap depicts – on a future time line – the drivers, markets, services, products, technology and related developments, which will be available or will be needed to achieve the vision. An efficient integration of these issues forms the path to the vision. When having the path identified, the required steps can be studied in more detail, and consequently, the needed actions can be identified and listed.

The visualization is inspired by the Graphic Gameplan developed by The Grove Consultants International

ACTION PLAN



MARKET ENTRY

Activating relevant industrial sectors and service sectors

Existing industries (textiles, health, construction, etc.) need to be ”shaken” to create space for new thinking and introduction of cellulose-based business. Involvement and active dialogue with industries is vital to create a positive environment to foster new cellulose-based markets. Service sector of each industrial sector need to be activated as well. Service sector includes also designers and other specialists.

Established value and retail chains

Eventually the new cellulose-based business will profit from complete value and retail chains that may evolve within existing industries or as partly new business and market structures. Existing industries, new businesses and entrepreneurship have all important roles.

BUSINESS DEVELOPMENT

Creation of a novel cellulose brand

The branding of cellulose-derived design products could be on different levels. The Finnish cellulose knowhow and network could be branded, the raw material (e.g. birch or highly appreciated long-fibre softwood pulp)or new cellulose-based materials could be branded according to their industrial applications, and each designed end-product using the materials could be the focus of branding work.

Business models and ecosystems

Development, piloting and fostering of appropriate business models and emerging business ecosystems. Understanding of opportunities needs to be deepened on topics such as: decisions to buy, retail chains, consumer segmentation, co-creation with customers and digitalization.

Cellulose factory; incubation and acceleration of business

To facilitate and boost business, especially SMEs, a cellulose factory could provide infrastructure and equipment to take the step from R&D results towards production. Entrepreneurial support and help for start-ups are included.

KNOWLEDGE NETWORKS

Creation of a joint database

A website to gather information and RDI results together and to facilitate networking and engagement of various stakeholder groups should be established. Events and information sharing could benefit businesses, researchers, student communities, user panels, etc.

Cellulose material bank

Knowledge of cellulose-based materials and related technologies to be collected to a material and knowledge library. Open access and sharing of knowledge to promote take-up of technologies and innovation.

Manufacturers' platform

An open platform for businesses and other stakeholders to support sharing and networking. Engagement of existing industries and encouragement to new businesses and entrepreneurs through knowledge sharing, events, seminars, awareness raising, PR, etc. (E.g. regarding construction industries co- operation with RT, RYM, FIBIC and FWR would be vital.)

Launching of the SELPA concept

"SELPA" concept has been created in DWoC project. The concept includes logistics and communication to reduce disposal to landfill and the consumption of virgin materials of novel cellulose based products in circular economy.

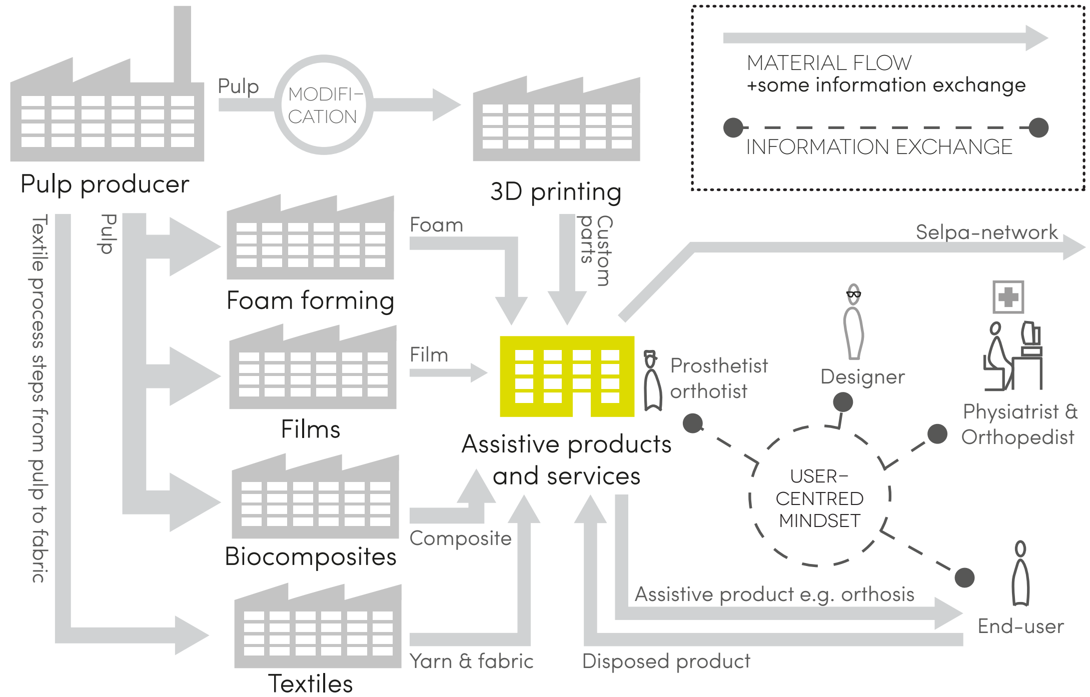
RESEARCH AND EDUCATION

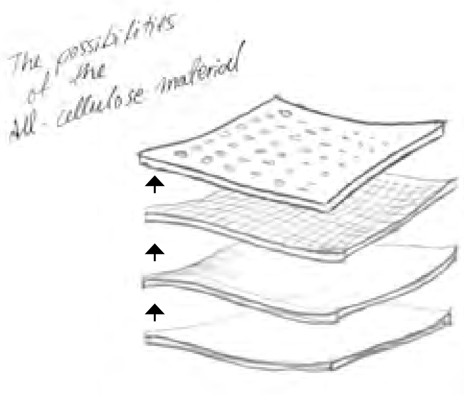
National research programme

Funding to intensive research to develop designed concepts, technologies as well as business is needed. In addition to DWoC 2.0 , FIBIC/Light biostructures and FIBIC/ACEL, other projects are needed. Tekes, FIBIC & RYM and RT programmes are examples of possible coordination channels. The entire RDI chain from basic research towards commercialisation should be covered.

Courses and education on novel cellulose materials and solutions

Education for young professionals is needed. Courses like "Cellulose I yarn based solutions for technical textiles and apparel" must be lobbed to universities and AMKs. Education ensures further knowledge creation and next generation of work force with technological capacity and business-mind to promote new cellulose-based business.





Cellulose can be used for various materials such as biocomposites, films, textiles and foams. These can be tailored to fit users' needs in assistive health care and sports applications. After use, they can be reused or safely disposed of.

Layers with different properties, for example, the next-to-skin layer breathable and non-absorbent and the outermost layer water- and dirt-resistant. Some layers stiff in order to restrain movement and others flexible in order to enable movement.

Design concepts

CASE: ASSISTIVE PRODUCTS FOR HEALTH CARE AND SPORTS APPLICATIONS

Susanne Jacobson, Tiina Härkäsalmi, Jukka Itälä, Marjaana Tanttu, **Aalto University**

In this concept, technically demanding product properties are met by means of cellulose-based materials. Orthoses are presented as an extreme example with complex technical, health care related and representational requirements. Cellulose is considered potential due to its biocompatibility, versatility and recyclability. The aim is to identify required material properties and ideate a layered structure. The goal is non-hazardous processes both in manufacturing and disposal.

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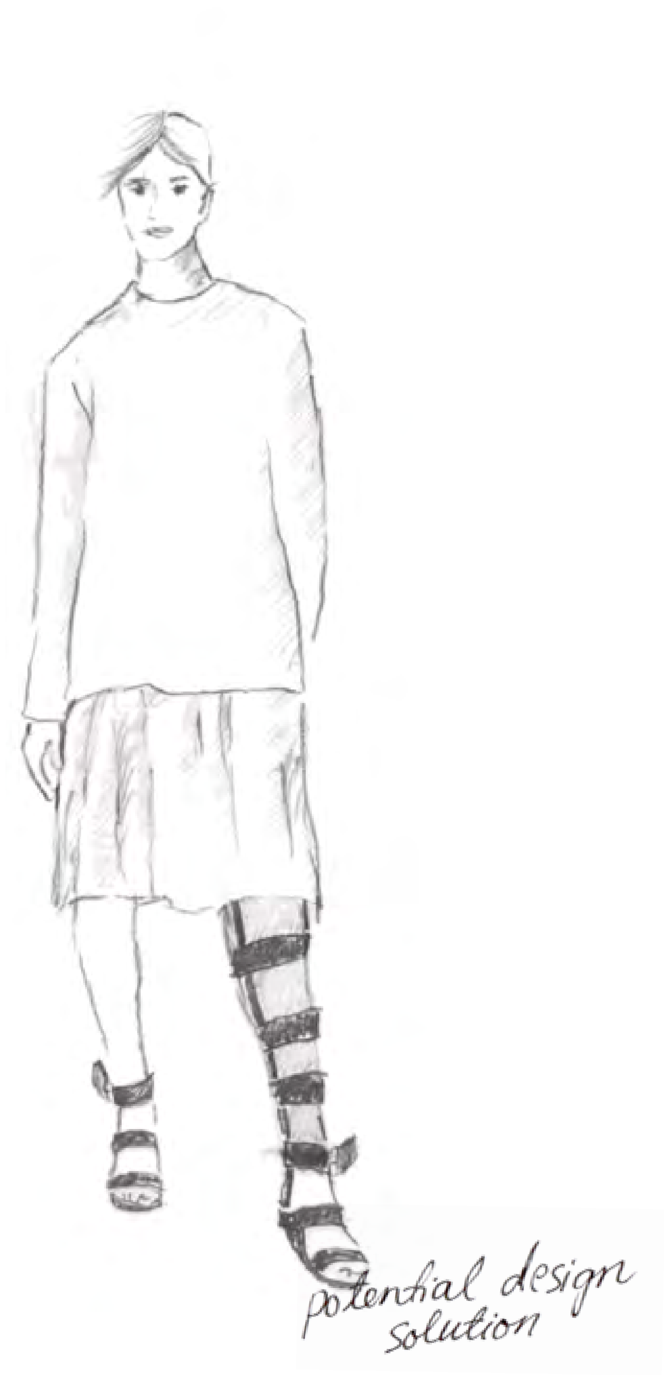


NEEDS

- As combinations of different materials and structures, current orthoses are difficult to reuse and dispose of.
- Current materials can be irritating as they may not be breathable enough and some of them are unhealthy to work.
- Orthoses need to be more wearable, easier and more convenient to use.
- Orthoses need to be unnoticeable and as thin, light and small as possible and represent their user's identity and lifestyle.

APPROACH

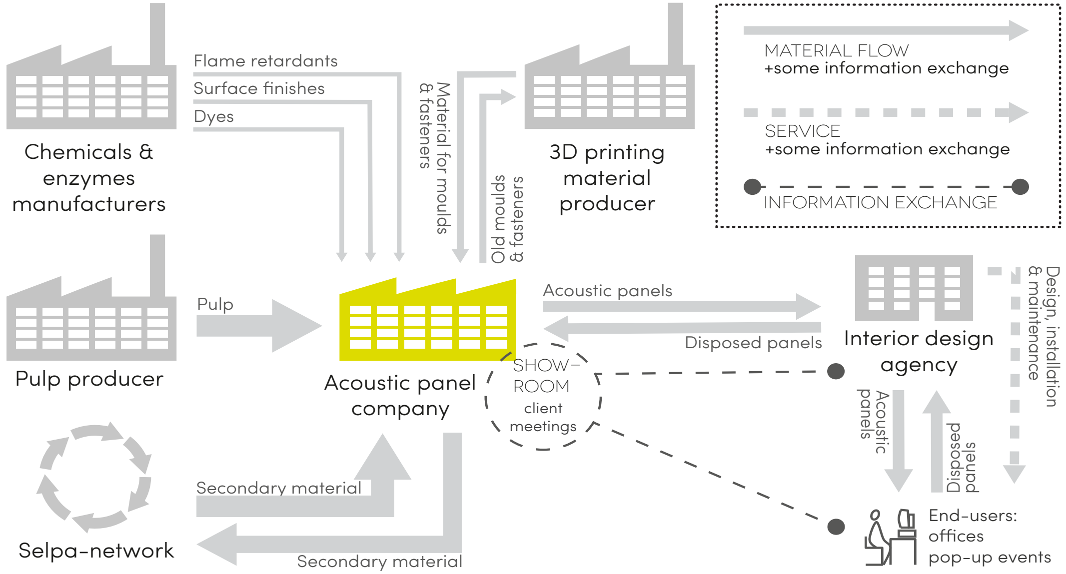
- Cellulose can be used for composites, foams, textiles, absorbing structures and films, which can enable different functions and structures. Layers can have different properties.
- The all-cellulose material enables reuse and a safe disposal.
- Cellulose-based materials can be moulded and finalised neat, which enables tailored products with both utility and aesthetic value.
- Supplementary functions can be added to the coreproduct, making the end-product more versatile and accepted.

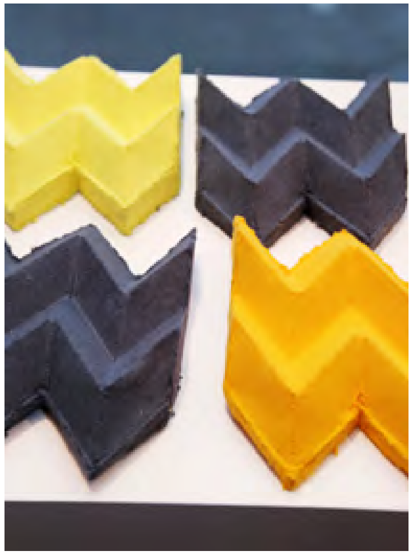
BENEFITS

- All-cellulose orthoses can be easily and safely worked, tailored, reused and disposed of.
- The properties of cellulose and and its manufacturing can enable multiple functions.
- Cellulose-based materials are comfort in use and do not seem to have negative associations.

COMPETITION

- Current rivals are difficult to reuse and dispose of due and they also have use-related shortcomings.





The utilization of pulp as a raw material for foam formed interior and construction applications enables novel business models that are based on closed-loop material cycles, and entail for example flexible product customization and product take-back.

Design concepts

CASE: FOAM FORMED ACOUSTIC PANELS

Tiina Härkäsalmi, Jukka Itälä, Marjaana Tanttu, **Aalto University**

Todays built environments house many challenges related for example to noise pollution, insulation, indoor air quality, renovation, and handling of construction waste. Materials selection has a big impact on all of these areas. For example the EU waste framework directive specifies that 70 % of construction and demolition waste should be recycled by the year 2020. This concept highlights foam formed pulp as a material for construction and interior applications, due to its recyclability and suiting technical and processing qualities.

NEEDS

- The reduction of noise pollution in home and work environments
- Customized and tailored solutions in construction and renovation
- The recyclability of construction materials and waste

APPROACH

- Using foam formed pulp for the production of sound absorbing and insulating panels
- The material's density, stiffness, permeability, heat insulation or sound absorption can be tailored
- All-cellulose product structures that are attainable through the variability of the cellulose as a material
- The form of the panels can be customized on multiple scales by moulding with 3D printed moulds
- Multiple colour variants can be produced by mixing pulp from just a few different colour batches
- Multifunctional products that can tackle various needs in construction and renovation

BENEFITS

- All-cellulose panels are easy to recycle after use
- The foam forming process is simple and requires a relatively light infrastructure
- The mouldability of the material enables tailored solutions for architects, interior designers and renovation contractors
- Possibility for new business models through customization, recycling and product take-back
- All of the cellulose material is used in the process, which removes excess sidestreams and waste

COMPETITION

- Various solutions made out of mineral and oil-based materials
- Panel structures that contain multiple materials glued together, making recycling impossible
- Also other cellulosic solutions exist, such as recycled cotton, but they are not as modifiable or foam formed structures
- Acoustic panels made out of non renewable natural resources for example turf

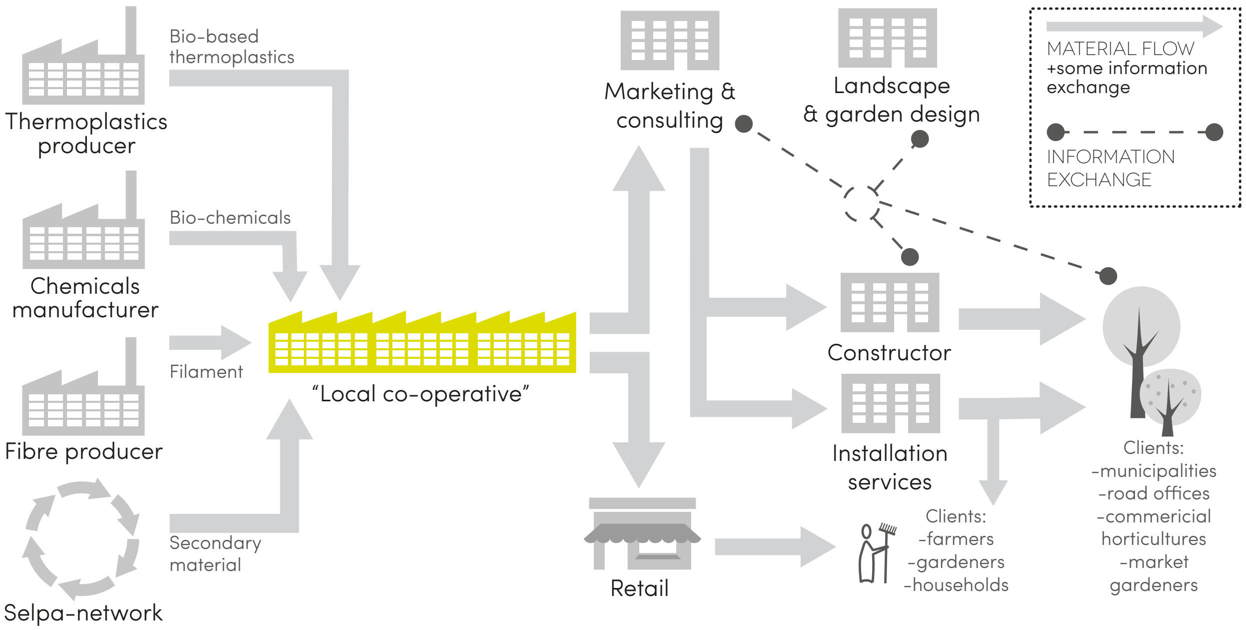
Design concepts

CASE: MULTI–SPACE OFFICE

Tiina Härkäsalmi, Jukka Itälä, Marjaana Tanttu,Minttu Somervuori **Aalto University**

Modern multi-space office answers to the challenge of using space more cost-effectively and efficiently. However it seems to be challenging for many of the employees to adapt to this new type of multi-space office environment. Products presented here are designed to ease the transformation from a cell office to a multi-space office, by creating products to improve the acoustic environment of the open spaces and creating feeling of privacy with space dividing elements. The business model presented in this multi-space office concept ensures that the material life cycle and end-use is taken into account.

The business model of this concept is based on leasing. After being used, the material is taken back by the leasing company and it can be reused as it is, or recycled as material. The spatial elements in the office can be easily dissembled and assembled again in a new office environment. The light weight of foam formed panels and the modularity of the design ensures that the assembling work can be done faster and with reduced human resources. After several life cycles, the material is finally used as a raw material for products in green building and agriculture. Trough SELPA system the origins of the material can be traced and the safety of the material can be verified.



This system map describes the stakeholder interaction of local production of biodegradable products in the distributed economy. "Local co-operative" is manufacturing products made of non-toxic cellulosic waste material to be used in green building, horticulture and agriculture and offering installation and design services.

Design concepts

CASE: BIODEGRADABLE PRODUCTS IN LANSCAPING AND AGRICULTURE

Tiina Härkäsalmi, Jukka Itälä, Marjaana Tanttu, **Aalto University**

This is an example of alternative small-scale manufacturing and related services of biodegradable products that are made of recycled cellulosic materials. The products are capable of controlled decomposing. Raw materials can be functionalized e.g. adding fertilisers, biocides or pesticides.

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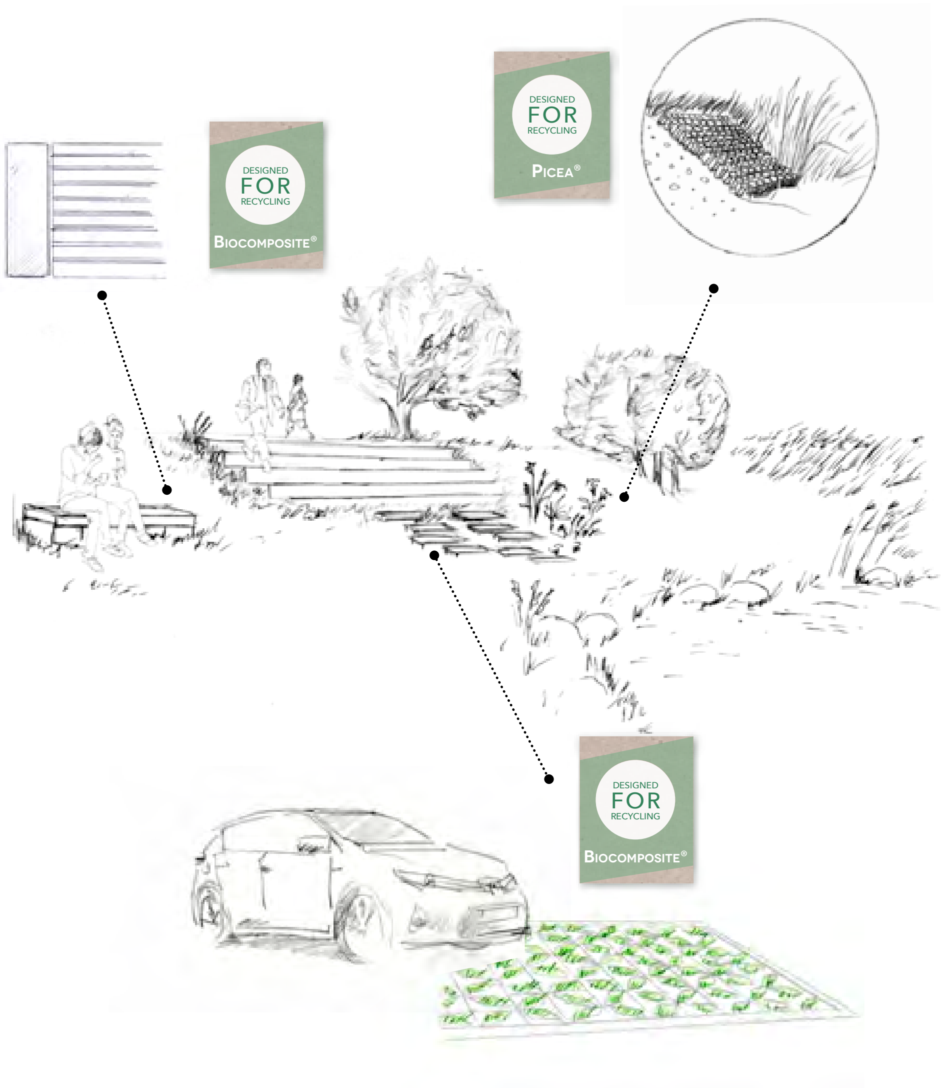


NEEDS

- to support the revegetation of environment and decreasing the rate erosion
- Absorption of flooding and urban run-offs
- Protection against pests

APPROACH

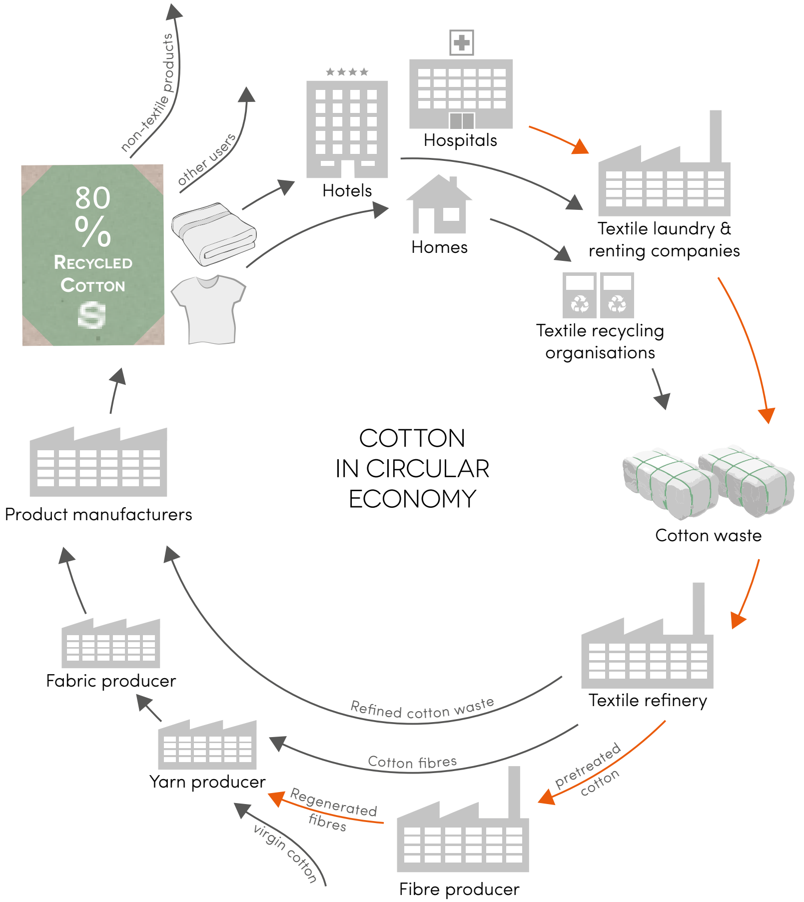
- Using recycled cellulosic materials at the end of their lifespan
- Biodegradable products that are used for rainwater absorption to the ground and maintaining an equable humidity of ground
- Objects that over the ground, e.g. seedling shields, anti-bird netting, tree guards and
- Objects that are buried in the ground, e.g. erosion blanket, slope mesh, baling net wrap, baler twines, weed control blanket) in controlled manner (short/long term degrading)

BENEFITS

- Valorisation and minimization of waste
- The hydrophilic nature of cellulosic materials is advantageous in water holding
- Biodegradability enables the natural growth of vegetation
- Can be applied in various product applications in green building, horticulture and agriculture
- Raw material can be functionalised e.g. adding fertilisers, biocides or pesticides

COMPETITION

- Current products in green building are mainly made of non- renewable raw materials e.g. in erosion control meshes of virgin raw materials (jute, straw) are integrated into the steel mesh structures
- In agriculture synthetic baling net wraps and baler twines



There are multiple ways to recycle cotton now and in the future:

- **producing textiles and other products directly from refined cotton waste (far future option)**

- **dissolving cotton for production of regenerated cellulose fibres (orange route researched in DWoC, see page 23)**

- **spinning longest cotton fibres directly back to yarn (already in the market)**

Design concepts

CASE: RECYCLING HOSPITAL TEXTILES

Tiina Härkäsalmi, Jukka Itälä, Marjaana Tanttu, **Aalto University**

The total amount of textile waste in Finland is currently 60–70 000 tons/ year, but it's expected to reach approximately 400 000 tons/ year in Nordic countries by 2020. So far there are very few solutions for recycling cellulose fibers in a way that would maintain the value of the material. The production of cotton cannot be increased.

NEEDS

- reducing the amount of organic waste that is taken to landfills
- to find a replacement for virgin cotton
- to find a system for textile recycling

APPROACH

- Producing high quality textiles with good moisture absorption for hospitals from recycled material
- Disposed hospital textiles are recycled into new products. A system of collecting and sorting broken textiles from hospitals already exists
- White textiles like sheets are easier to recycle than dyed fabrics

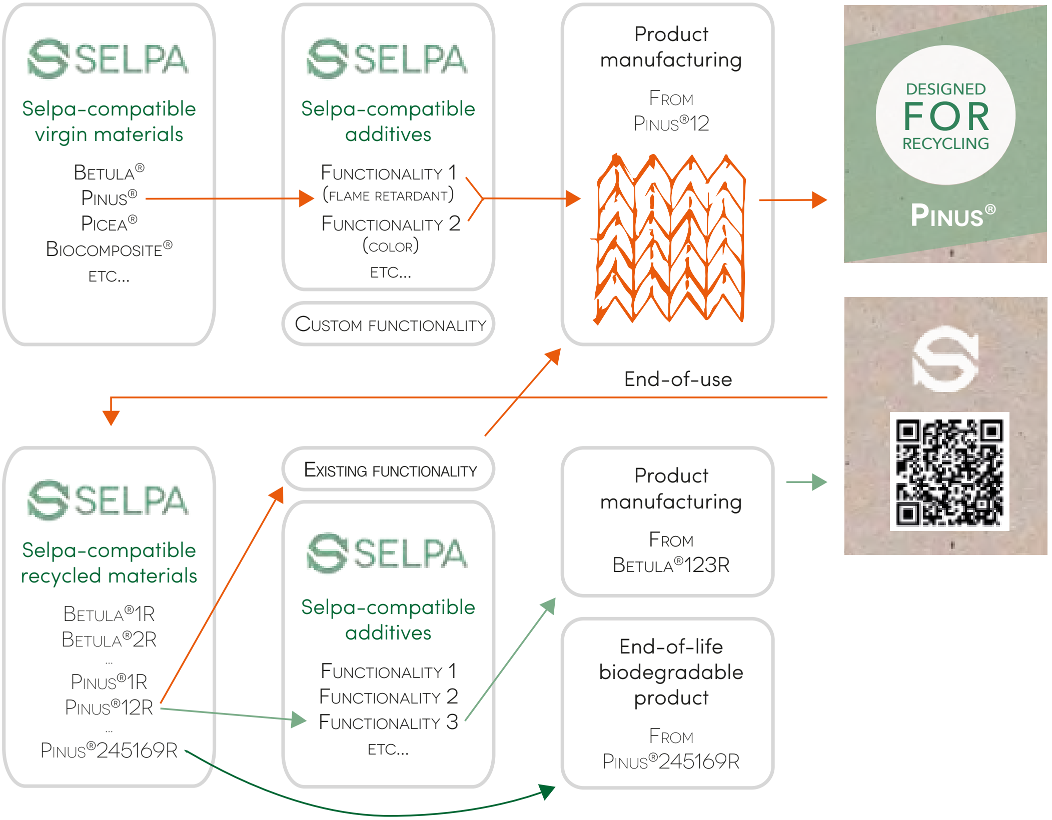
BENEFITS

- Since the amount of textile waste is so large, developing recycling systems provides a great potential for waste minimisation and valorisation
- This concept is ideated to support the development of circular bioeconomy. Through this network stakeholders can gain positive impact to brand image by contributing to sustainable development

COMPETITION

- Main competitors are disposable textiles and synthetic materials
- Creating a network is a beneficial approach, because processes can be adjusted to fill the specific needs of different partners

SELPA RECYCLING SYSTEM



Tiina Härkäsalmi, Jukka Itälä, Marjaana Tanttu, **Aalto University**

SELPA is a system that includes logistics and communication to reduce disposal to landfill and increase the consumption of secondary materials. At the moment biggest challenges in secondary materials are supply, quality and uniformity of recycled material.

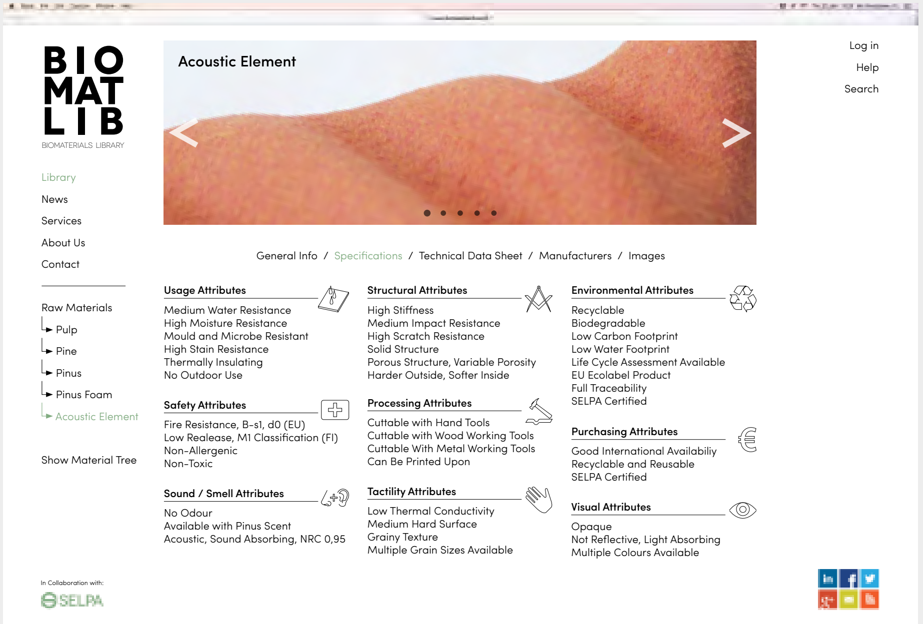
SELPA aims to solve the problem of using suitable virgin or secondary material by coordinating a portfolio of materials and additives suitable for recycling, and organising traceability of the material to control that it can be recycled in the best possible manner. A product manufacturer can ensure manufacturing recyclable products by choosing the raw material and required functionalities from Selpa portfolios of materials and additives. Products made from Selpa-compatible ingredients are entitled to use Selpa labels in their marketing. Selpa label ensures recyclability and traceability of these products. The code related to a product tells what raw material (Pinus) and additives (flame retardancy and color) have been used, and if it's a recycled material (R). Once these products come to end-of-use, they can be used in

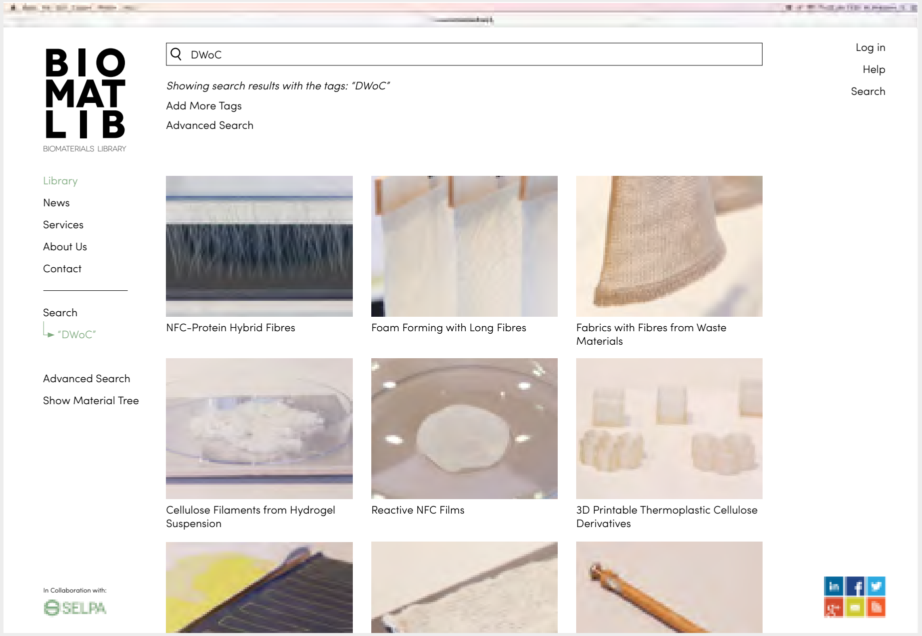
- **same product types, when existing functionalities are already enough (orange route)**
- **new product types, when new functionalities are added (light green route)**
- **in end-of-life product type, when it's not anymore suitable for other purposes (dark green route).**

Enabling systems

BIOMATERIALS LIBRARY

The **Biomaterials Library** consists of two parts: a showroom space containing tangible material samples that enables also the palpable exploration of materials, and an online digital database through which materials related information can be easily accessed. The Biomaterials Library concentrates on collecting, storing, and sharing information of bio-based materials, starting initially with cellulosic materials. The library is a non-profit independent operator that aims at sharing information between different stakeholders from universities, research organizations, and industry in order to support collaboration and the generation of innovation and new business around biomaterials.



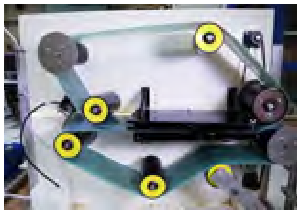


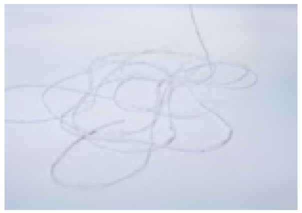


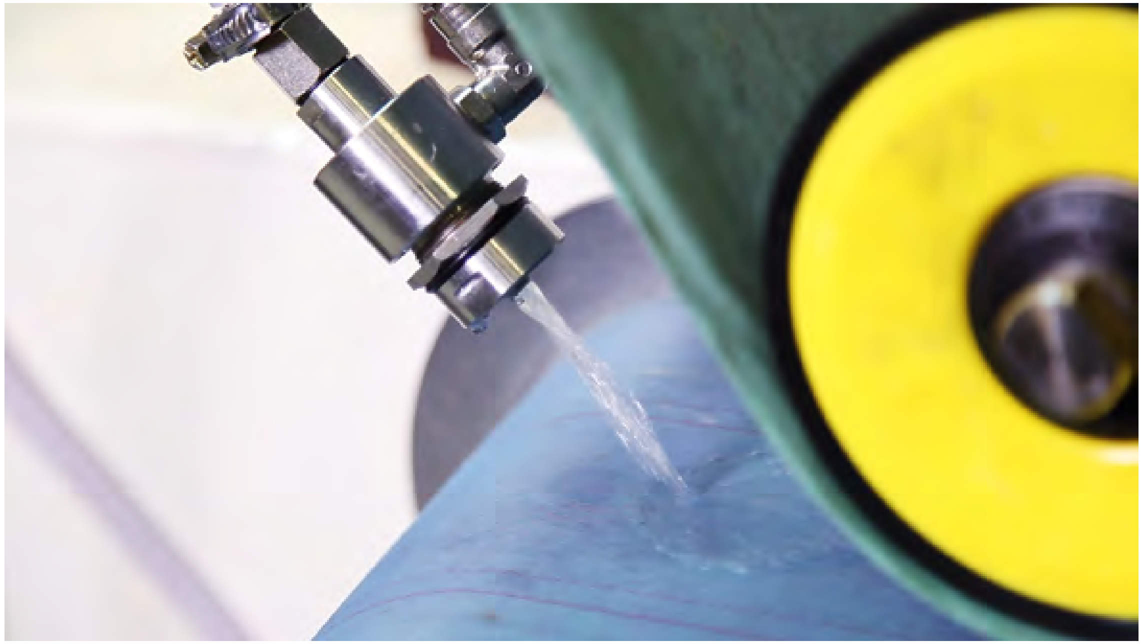
Enabling systems
CELLULOSE FACTORY

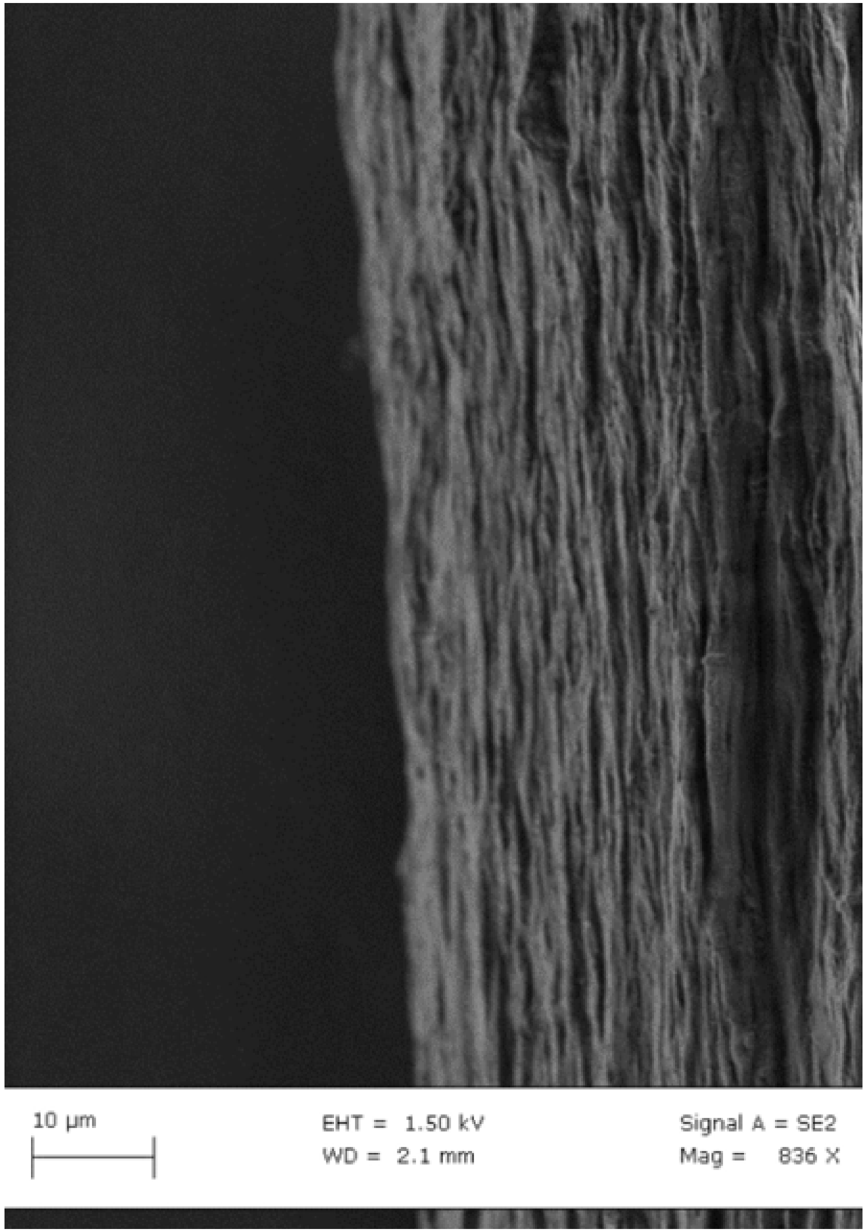
Interdisciplinary collaboration, exploration and knowledge sharing is essential in the creation of new business opportunities. The **Cellulose Factory** (CF) is a response to these needs in the field of cellulose. The goal of the CF is to facilitate collaboration between different fields and stakeholders to incite cellulose-related innovation. It aims to be a prototyping platform for students, researchers, designers, engineers and other professionals from research institutes and companies from small to large. CF can offer an access to different types of cellulosic materials, modular equipment for prototyping, small scale production and testing.

CF facilities will be located at the Otaniemi campus of **Aalto University**, at the **School of Chemical Technology** (CHEM). It will be a part of the joint Bioeconomy Infrastructure of **Aalto University** and **VTT**. The Bioeconomy Infrastructure is included in the roadmap for research infrastructures updated by Academy of Finland (2014-2020).









ENABLING TECHNOLOGIES

One of the most important goals of DWoC has been to explore and challenge the existing and emerging technologies, and to analyse and test the design and business potential of findings. Alongside technical properties the focus has been on developing a designedly interesting/desirable materials for versatile use in products, fulfilling future customers' demands (consumers or/and b to b).

The technology development in DWoC 1.0 focused on new ways to constitute yarn like continuous filaments from pulp cellulose, use of waste cellulosics as raw materials for regenerated fibres, exploitation of paper machine as tool to manufacture textile like structures from cellulose fibres with the foam forming method and using 3D printing as tool to create textile structures.

HIGH TENACITY REGENERATED CELLULOSE FIBRES FROM RECYCLED COTTON

Shirin Asaadi, Michael Hummel, Tiina Härkäsalmi, Herbert Sixta, **Aalto University**

Potential applications

The fibres spun from waste textiles show excellent tensile properties and also relatively high elastic moduli. Consequently, they can be used as textile fibres or high-value products such as biocomposites. Currently, we are improving the properties of the fibres by blending the recycled cotton with different pulps.

Characteristics

The bed sheets were cut into small pieces and ground in a Wiley mill with 1 mm sieve. The initial viscosity of the material was 750 ml/g which had to be adjusted to 450 ml/g. Acid hydrolysis was utilized to degrade the materials to reach the target viscosity. After viscosity adjustments, hydrolyzed recycled cotton was dissolved in the ionic liquid. The shear rheological characteristics of the cellulose-IL solutions were assessed. Then, multifilaments were spun at specific conditions. Plain water was used as a coagulation medium and fibres were produced with draw ratios of 0.88 to 8.84. The analysis of the spun fibres showed that their tenacity was comparable to Lyocell fibres.

Background

Man-made fibres constitute 60 percent of the world fibre consumption. Consequently, the textile industry has a significant interest in a constant further development of these fibres. In this field, the environmentally friendly production is one of the dominant challenges- and an opportunity at the same time. The textile industry is looking for more sustainable technologies in fibre and fabric manufacturing. One of the most important issues that need to be investigated is the resource efficiency that deals with waste, water and energy management. Reducing the use of toxic chemicals in fibre manufacturing processes is also of significant importance.
In this project the production of man-made cellulosic fibres is done successfully by dry jet-wet spinning of recycled cotton-ionic liquid solutions.

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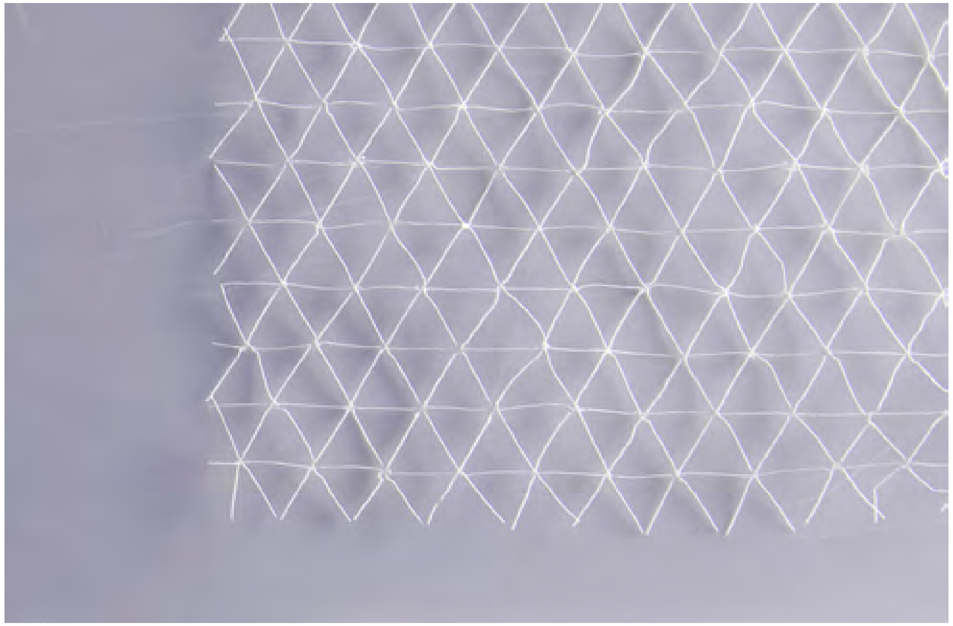
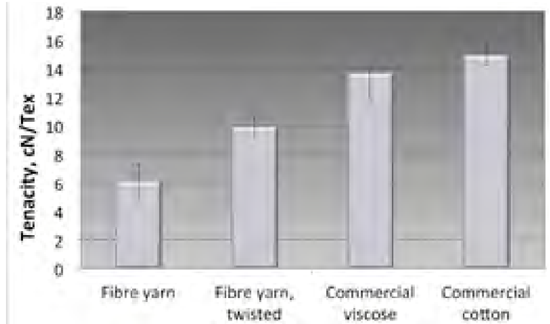


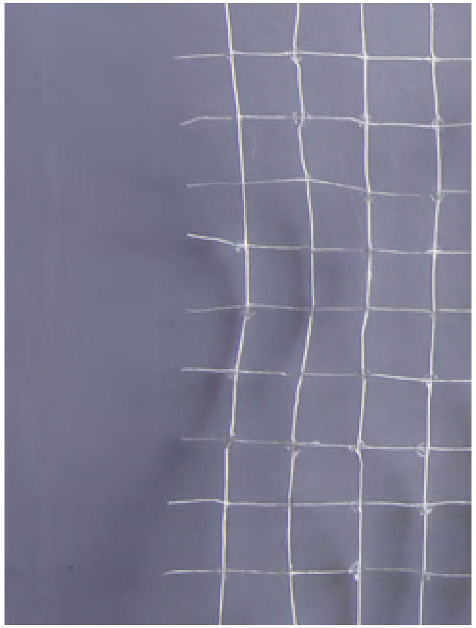


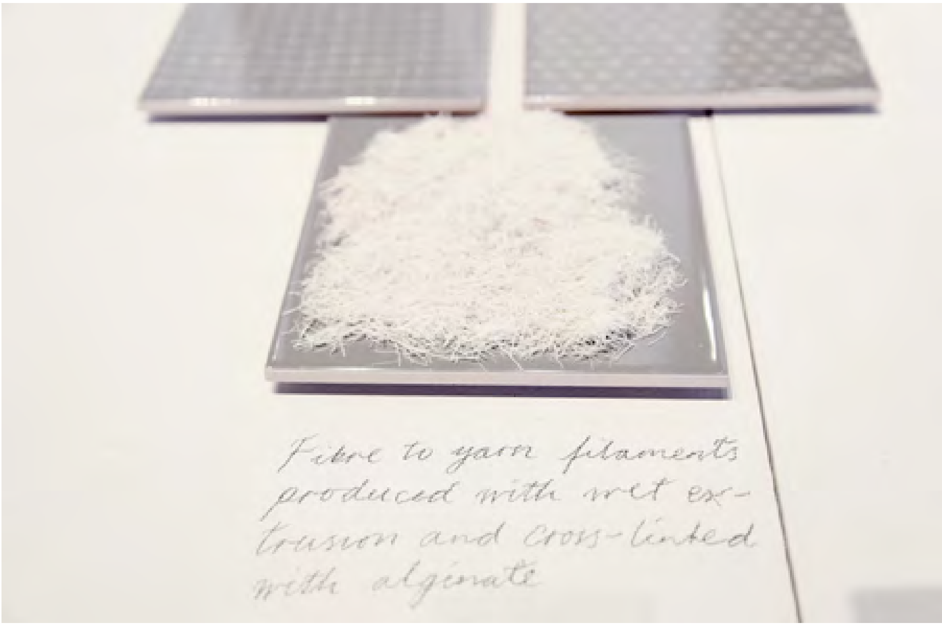
NOVEL CELLULOSE FIBRE YARN

Johanna Liukkonen, Jarmo Kouko, Juha Salmela, **VTT**

Background

Currently there is no truly sustainable pathway for the production of textile yarns. Consumers, industry and governments are increasingly demanding products that are biodegradable and made from renewable raw materials using environmentally friendly manufacturing processes. An important class of consumer products of wide use is fabrics made of natural or synthetic filaments and yarns, and used e.g. in producing a wide variety of industrial or clothing textiles. A promising new technique for producing man-made yarns directly from wood fibre suspension by a wet spinning process was recently introduced by VTT. The method has potential of producing low cost yarn with adequate mechanical properties and very low environmental impact.





Characteristics

The strength of a fibre yarn depends strongly on the fibre orientation and on the type of bonding between fibres. Fibre to yarn process utilizes shear-induced self-organization inside a specially designed nozzle to achieve good fibre orientation. Fast cross-linking with alginate gives the yarn adequate initial wet strength. Currently fibre yarns have been produced in laboratory scale. Developed technology enables production of wide variety of yarns starting from 10 Tex filaments with diameter less than 100 μm. Tensile properties are already close to the commercial yarns. Colored fiber yarns can be produced, and smoothness, stretch and hydrophobicity can already be somewhat adjusted.

Potential applications

The results will facilitate design of a viable industrial-scale spinning process for wood fibre -based textile yarn without dissolving process. In the middle or long term, wood fibre -based yarn has the potential of replacing cotton and viscose in many textile products, prospects for a broad use of wood fibre yarns in apparels and technical textiles are good.

FABRICS KNITTED BY FIBRES MADE FROM WASTE MATERIALS

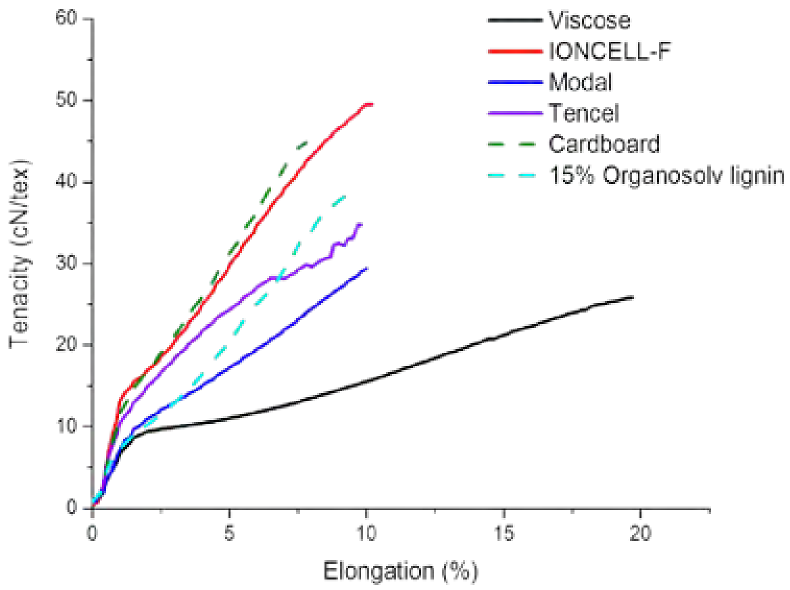
Yibo Ma, Marjaana Tanttu, Shirin Asaadi, Michael Hummel, Herbert Sixta, **Aalto University**
Marjo Määttänen, Airi Särkilahti, Ali Harlin, **VTT**

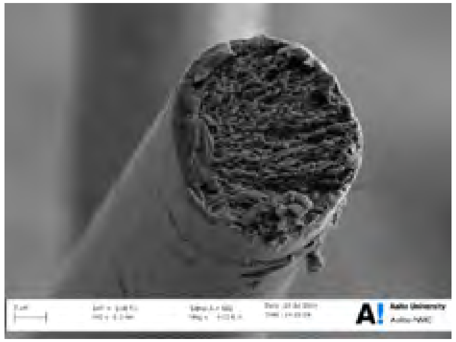
Background

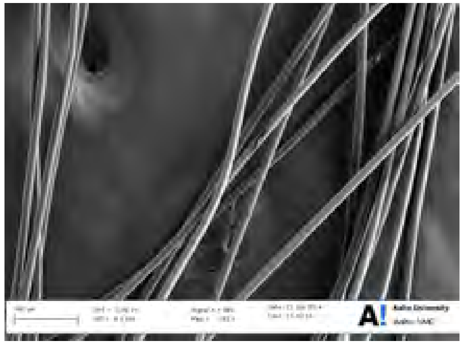
Increasing environmental concerns have promoted the recycling of waste cellulosic material to reduce landfill and harvest of trees for production of cellulose. The efficient recycling of these materials significantly reduces the environmental impact and can potentially upgrade them to valuable products. In this demonstration, different fabrics were produced from fibres that were made from recycled paper, card board and a dissolving pulp/lignin blend. The staple fibres were spun via a dry jet-wet spinning process which utilizes an ionic liquid as solvent, referred to as IONCELL-F process. Compared to the viscose and Lyocell fibre processes, the IONCELL-F process is considered to have a reduced environmental impact. Using recycled materials as cellulose sources ensures the ecological sustainability of the fibres and can also reduce the raw material costs, which typically constitute the biggest share of the production costs. Additionally, the use of unbleached card board and dissolving pulp/lignin blends aims to produce naturally dyed textile fibres.

Characteristics

Pre-treated card board with a small amount of residual lignin was dissolved in ionic liquid with a concentration of 11.5 wt%. Dissolving pulp was blended with organosolv lignin at a ratio of 17:3 and mixed with the ionic liquid to produce a 15 wt% dope. The dissolution was carried out at 80 ˚C for 1.5 hours, while the extrusion temperature of the spinning dope was lowered to 70 ˚C. Thus, both dissolution and spinning temperature are substantially lower than in the Lyocell process. The coagulation medium was water. No other chemicals, but only ionic liquid and water were involved during spinning according to the IONCELL-F process. The fibres made from recycled card board and from lignin/cellulose blends have slightly lower tenacity than those produced from dissolving pulp due to higher hemicellulose and lignin contents. However, both fibres exhibit a unique golden and brown exterior in different shades, respectively. In this way, the incorporation of varying amounts of lignin either in the form of residual lignin in the cellulose substrate or of lignin/cellulose blends can be considered as a natural dyeing process.







Potential applications

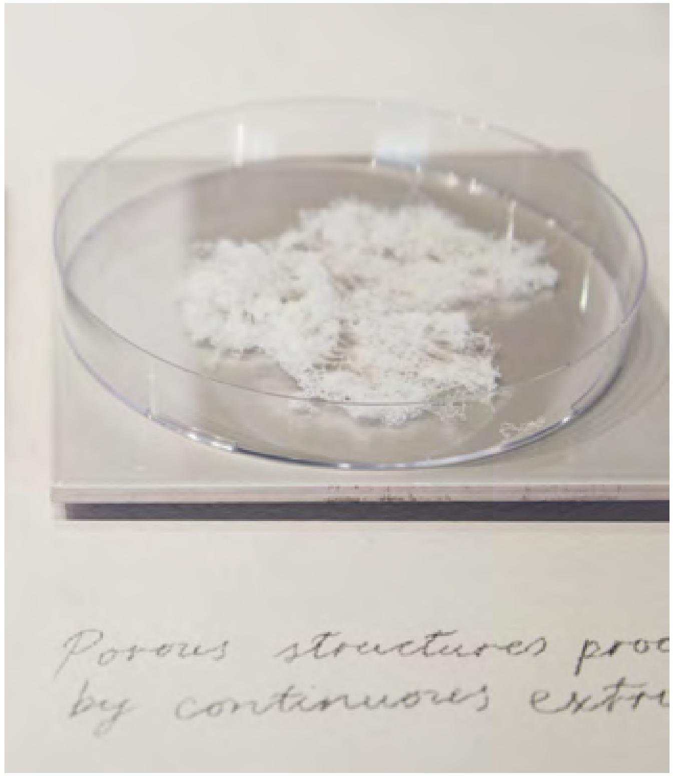
Fibres spun from recycled material and cellulose/lignin blend proved suitable for textile applications due to their excellent tensile properties. The spun fibres have been converted to yarns in University of Borås, Sewedish Schoocl of Textiles and followed by successfully knitting of different fabrics at Aalto University. The lignin in the cellulosic raw materials added a naturally brown shade to the fibres. The color and color depth can be tuned by the lignin source and the lignin content in the fiber. In addition, the relatively high Young's modulus suggests that the fibers can be even utilized in bio-composites for e.g. automotive applications. The cellulose/lignin blend fibres are also suitable as pre-cursor for carbon fibre production, as the elevated carbon content in lignin increases the carbon yield upon carbonization.

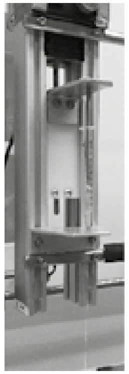
CELLULOSE-BASED FILAMENTS FROM HYDROGEL SUSPENSIONS

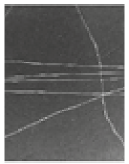
Arto Salminen, Steven Spoljaric, Jukka Seppälä**, Aalto University**

Background

Fibrillated cellulose possesses impressive strength properties due to its crystalline domains, which may yield beneficial features in fibre and yarn applications. However, the inherent brittleness and poor water stability of cellulose prevents its broader application. Furthermore, the poor wet strength of neat cellulose suspensions make it unsuitable for filament spinning. To overcome these hindrances, the wet-strength of cellulose suspension was improved prior to spinning. The modified cellulose suspensions are easily spinnable due to the influence exhibited on wet strength and dope morphology. Due to suspension modification, dry filaments exhibit improved strength, structural integrity and material stability. In addition, filament water stability can be enhanced via surface coating or heat treatment.







Potential applications

Spinnability from water allows a straight-forward route of manufacturing non-woven structures, applicable as décor or designer products. Furthermore, the strong adhesion of the filaments while still wet shows great promise in preparing multi-filament yarns. Similarly, these could be applied for interior decorative applications as an alternative to cotton-derived yarns.

Characteristics

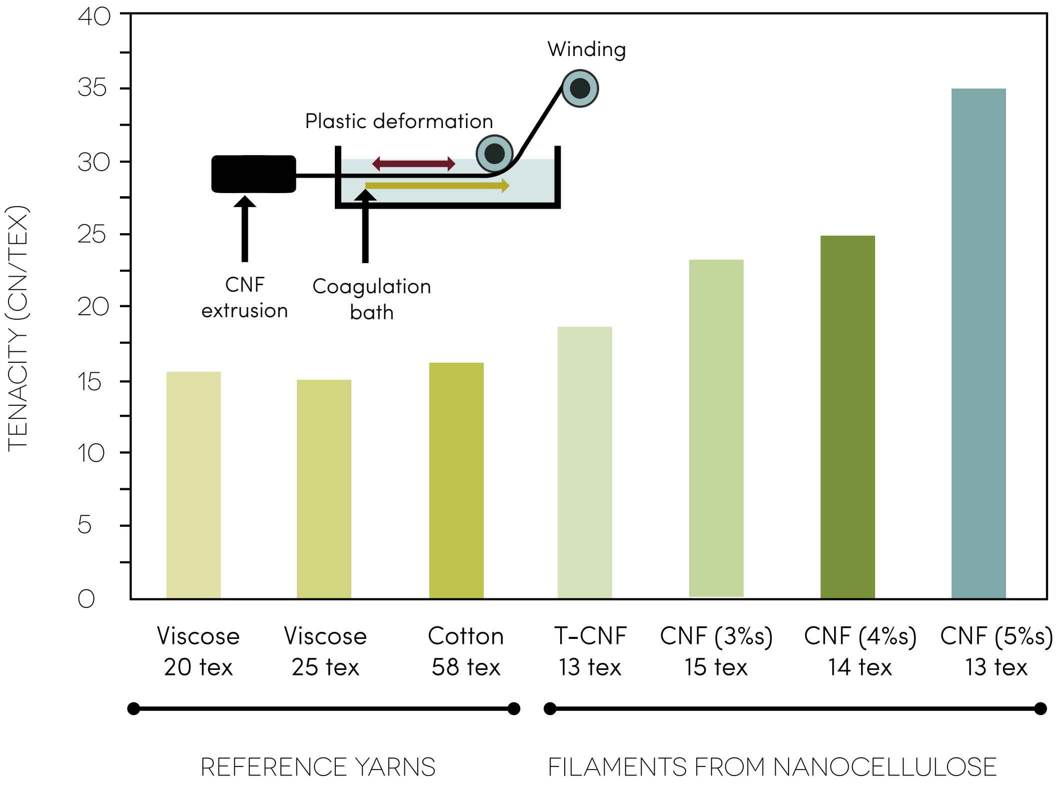
Thin filaments (approx. diameter 0,03-0,1 mm) could be easily spun/ extruded using a semi-continuous method. Filaments exhibited titer values higher than viscose and similar to cotton yarn, while tenacity values were slightly lower than both viscose and cotton. The ductility of the cellulose-based filaments was limited, due to strong bonding between the filament components. Aside from poor ductility, water stability was another critical property – this was enhanced by coating the filaments with titanium dioxide and subsequent heat treatment. Post-treatment of dry filaments with multi-functional carboxylic acid also enhanced water stability.

SPINNING OF NANOCELLULOSE SUSPENSIONS

Ester Rojo, Meri Lundahl, Julio Arboleda, Miika Nikinmaa,
Ilari Filpponen, Hannes Orelma, Orlando Rojas, **Aalto University**
Hille Rautkoski, Maria Soledad Peresin, Ying-Feng Shen, **VTT**

Background

The aim of this research is to develop high performance, continuous fibres using native cellulose nanofibres (CNF). Crystalline regions in CNF have been reported to have Young's modulus as high as 138 GPa. Thus, the high crystallinity and the presence of Cellulose I suggest a superior mechanical performance of CNF-based fibres compared to existing cellulosic materials (cotton and regenerated cellulose fibres with Cellulose II, for example). Such favourable performance can be augmented if CNF is aligned properly during the spinning process. The challenge is to spun fibres based on CNF as single component.

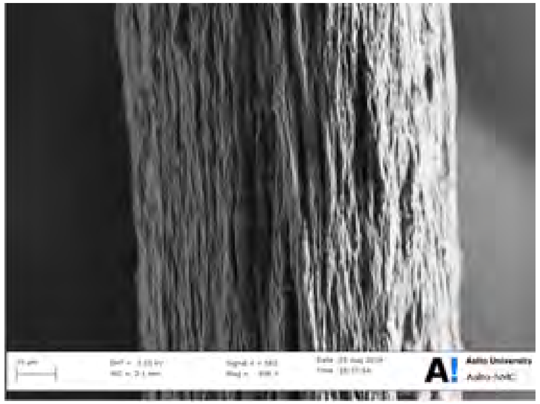


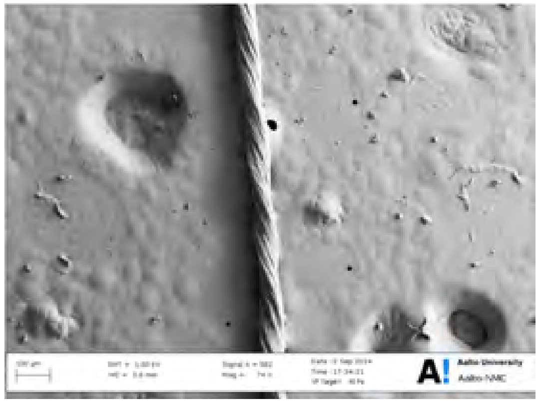
Characteristics

Wet-spinning is a promising method to align CNF from aqueous suspension in the form of macroscopic filaments. It also avoids changes in crystalline structure that otherwise occur in cellulose dissolution. Wet-spinning can enable the production of super strong textile-grade fibres from an abundant and renewable resource, namely wood. Long fibres (≥60 cm) were obtained from 100% CNF in a wet-spinning line. Tenacity, elongation, and titer of the strongest fibres tested so far are 35 cN/tex, 15 % and 13 tex, respectively. Currently, we are focusing on the improvement of alignment and the wet-strength of the filaments to provide water resistance and facilitate continuous and scalable process.

Potential applications

Spun fibres from CNF can be directly featured in composite materials. They can be used as composite strength reinforcement because of their internal alignment. Composites reinforced with CNF-based fibres will be useful in materials requiring high strength and low weight, such as technical textiles for transport and construction. In addition, surface functionalization can be easily implemented during wet spinning. The cellulose I crystal structure provides a smooth feel to the skin and wears comfortably in clothing and therefore CNF-based fibres are an attractive alternative to cotton.





BIO-INSPIRED NEXT GENERATION FIBRE THROUGH ENERGY DISSIPATING LINKAGE

Pezhman Mohammadi, Sanni Voutilainen, Markus Linder, **Aalto University**

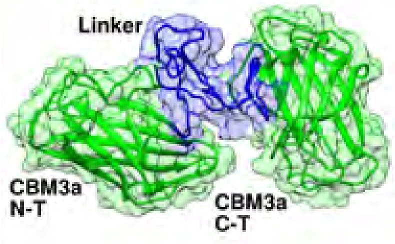
Background

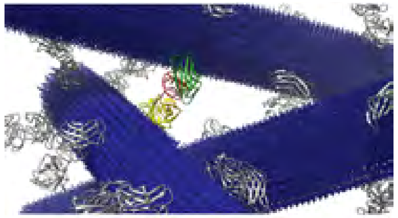
Self-assembly of molecular units into hierarchy of complex and functional superstructures is ubiquitous in biology. Icosahedral viruses, diatoms, nacres, spider silk and cellulose fibers are just a fraction of some of the most amazing shapes and extraordinary materials biology created with a same principle.

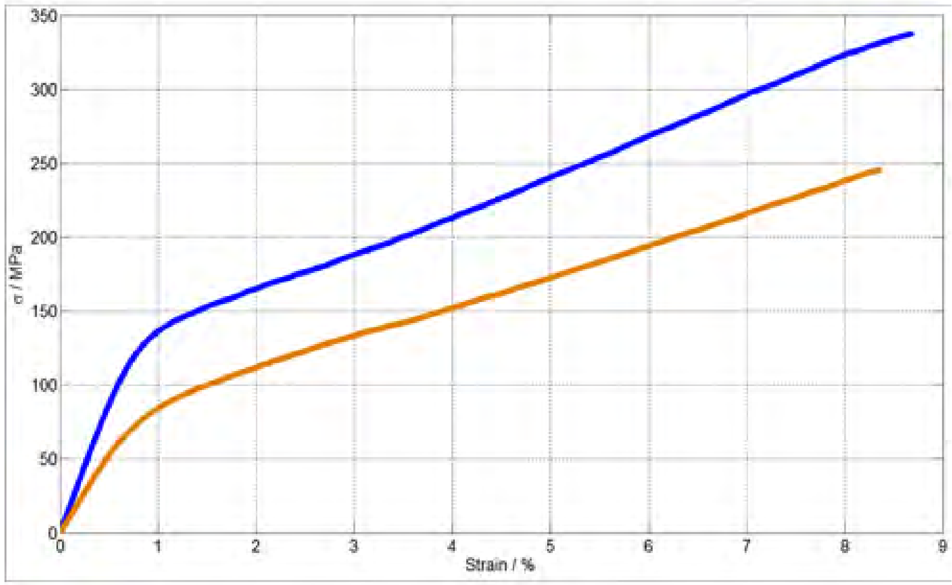
Over the past years, molecular self assembly becoming increasingly a hot topic and biologist have been inspired by the nature's assembly roles to create artificial materials using biological building blocks for constructing materials with high level of order, complexity, precision, dynamics and adaptation for medical and industrial applications. Proteins and peptides are one of the most wildly studied self-assembling functional building blocks among all.

The feasible design, synthesis, specificity, bioactivity, biodegradability, makes proteins a perfect structural unit for the bottom-up formulation of next generation of nano-bio-materials. However deep understanding of the structure function relation and fabrication of new materials is required.

We are developing a novel and innovative approach to produce next generation bio-composit hybrid fibers, using recombinantly produced genetically engineered fusion proteins and Nanofibrillated cellulose (NFC). Due to fundamental structural and functional differences between fusion proteins and NFCs, a hierarchical reinforcement is created, where NFCs are the primary load caring reinforcement elements and fusion proteins forms a matrix of nano-glue cross-linker at interphase around the NFCs acting as the secondary load caring elements. With this approach we are able to produce strong fiber and films with comparable mechanical properties to natural fibers.







Stress-strain curves of the **NFC-protein filament** (blue) and **pure NFC filament** (orange)

Characteristics

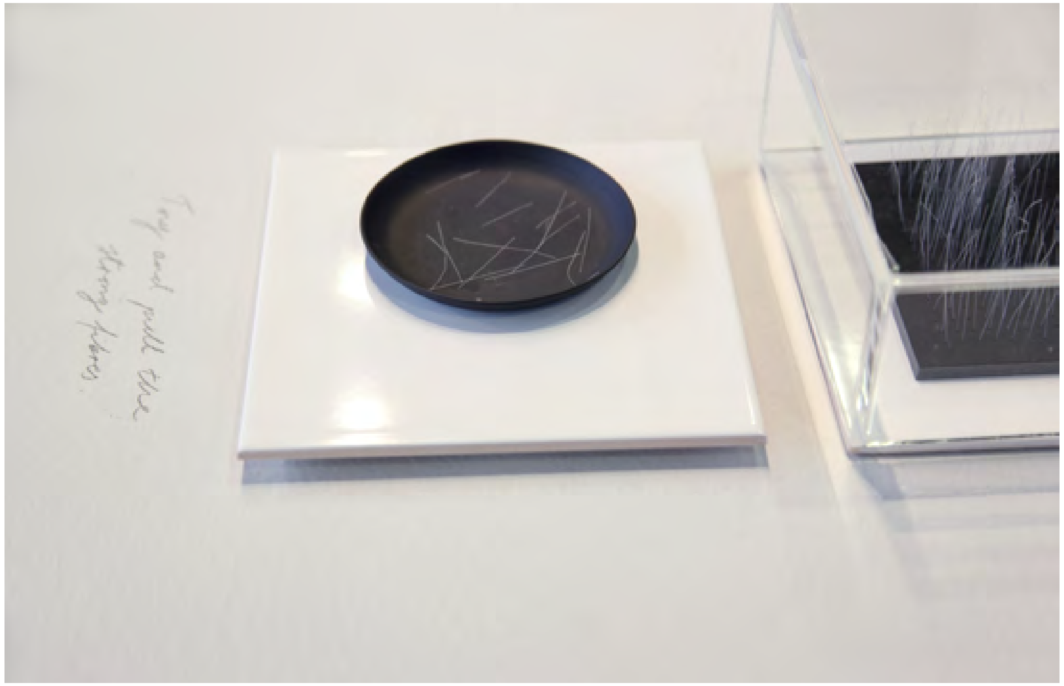
Individual filaments made with our approach has tensile strength of 351 MPa , higher than natural fibers such as Cotton (225MP) and Hair (300 MPa). Combination of strength and extensibility up to 10% provides toughness around 23.91 J/m-3 to these filaments. Young's modulus or elastic modulus of our material is 20.18 GPa which is much higher than natural fibers such as Spider dragline silk (8 GPa), Cotton (7.9 GPa) and wool (1 GPa)

Pros

- Biodegradable , Biocompatible and renewable
- Material made entirely without use of any harmful solvents or chemicals
- Green manufacturing process. reduce many of the toxins and pollutants used in conventional petroleum based fiber and polymer production process.
- Light weight with high strength and stiffness
- Low cost of manufacturing

Cons

- Low wet strength (Note: There are many approaches to overcome this problem and we are currently investigating what is the best rote toward making our materials water resistance without compromising any of the positive characteristic of our filament from mechanical and biocompatibility as well as fabrication point of view)



Potential applications

Textile

- The market for technical textiles is in excess of $120 billion annually. Cellulose based technology has the potential to revolutionize industries here in Finland and worldwide

- Ropes, nets, seat belts, parachutes

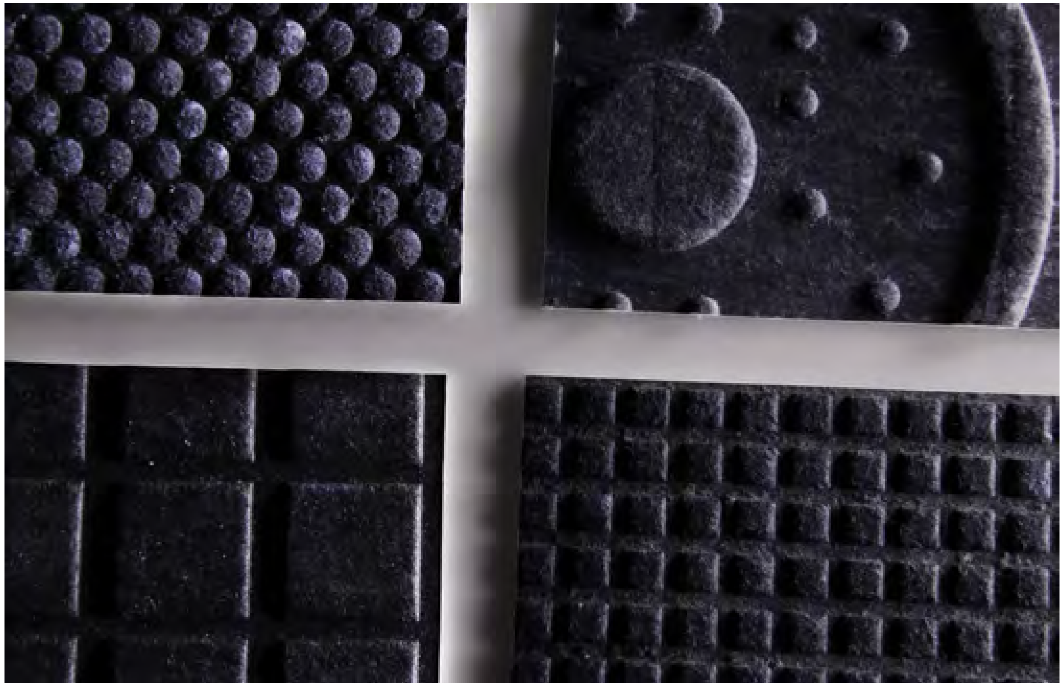
Medical application

- Bandages, surgical thread

- Artificial tendons or ligaments

- Scaffold for tissue engineering/regenerative medicine

- Implant surface coating

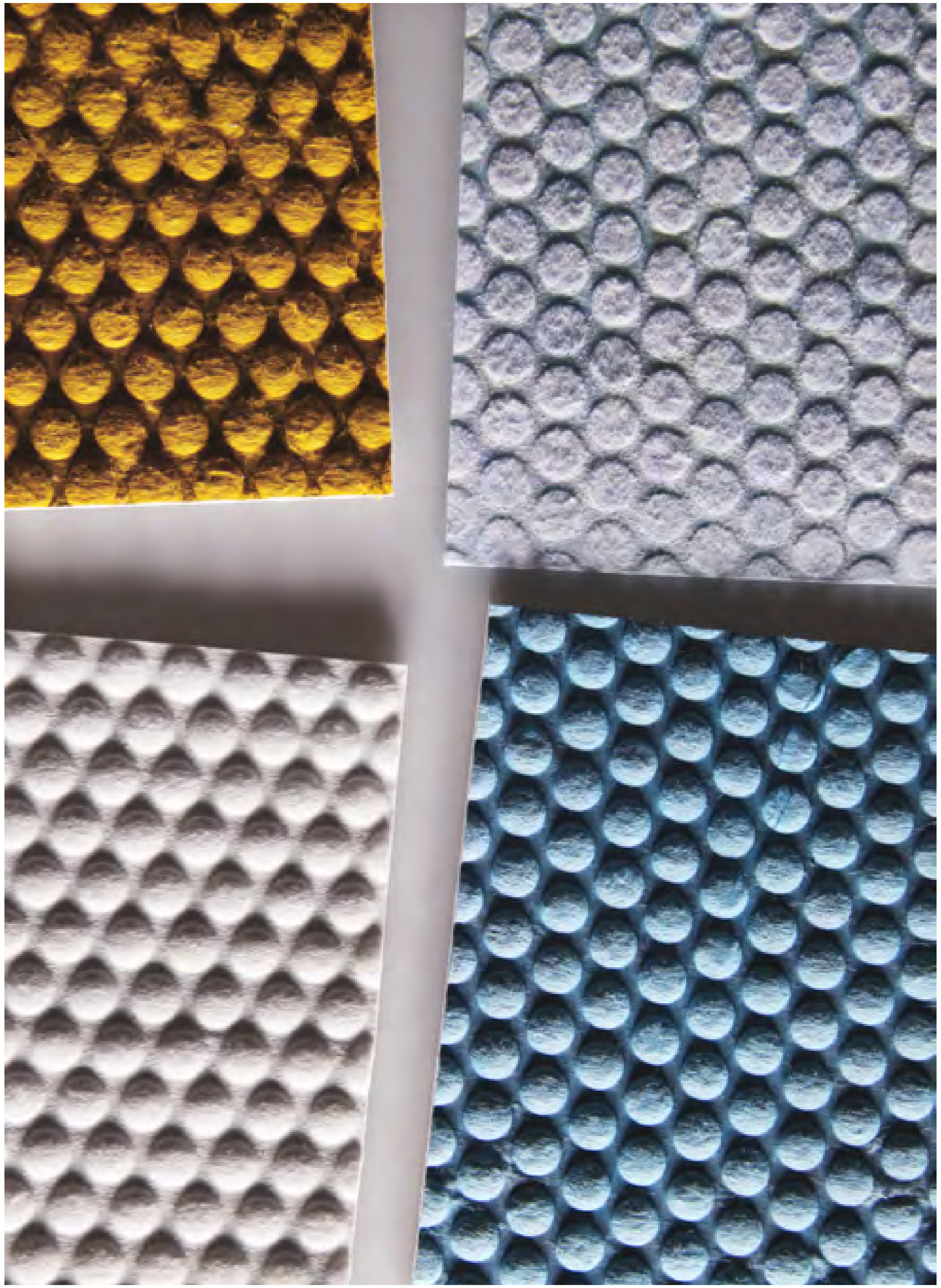


EXPLORING COMMINGLED BIOCOMPOSITES

Tiina Härkäsalmi, Iina Solala, Jukka Itälä, Marjaana Tanttu, **Aalto University**

Background

In this work commingled composites were researched through explorative prototyping to discover their thermoformability and sensorial quality, especially visual and tactile properties.
There are natural fibre reinforced composite materials in the market, but usually they have non-renewable matrices. As a result the end products are difficult to recycle and are normally disposed in landfill. Therefore this work focused in material combinations that are completely renewable and biodegradable. Commingled composite material was chosen to be explored for various reasons. Commingled composites are produced by intermingling the fibres of the matrix and the reinforcement material, and no solvents are required to blend the materials. Pre-finished products can be manufactured with non woven methods, and can subsequently be thermoformed into a final product. non woven methods are rapid and cost-effective ways of producing fabric. Non wovens are commonly used in disposable products. The aim of this study was to explore their potential use in new applications and new context.



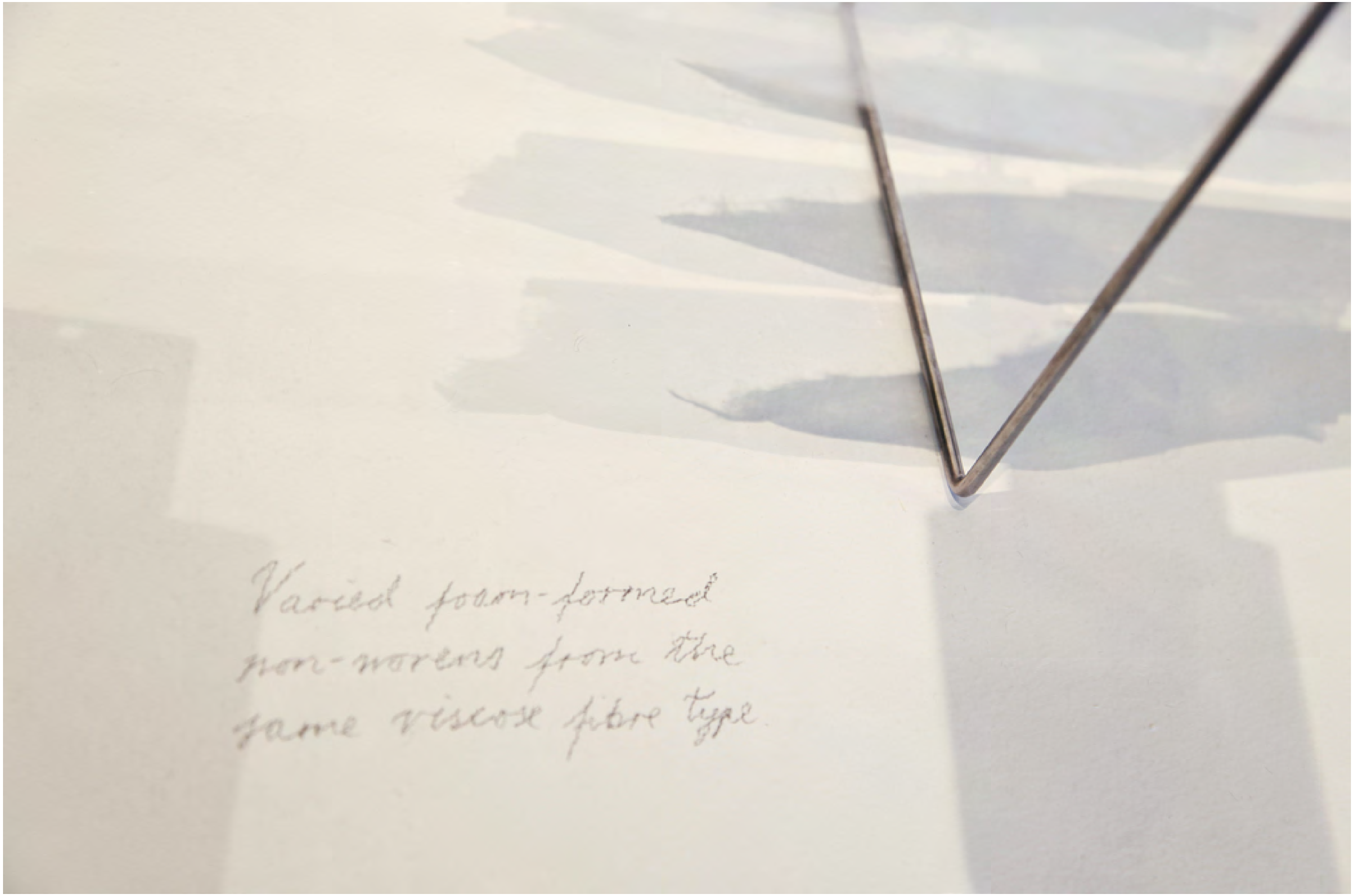
Characteristics

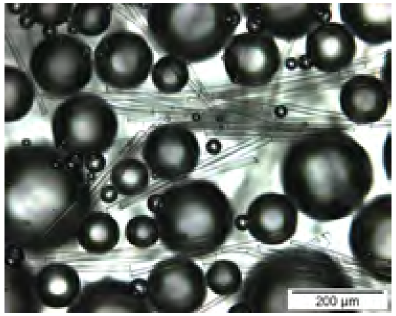
Commercial IngeoTM polylactic acid (PLA) is the matrix in all the composites. PLA is biodegradable aliphatic polyester commonly derived from corn or potato. However, its brittleness can limit its usability, which is why a reinforcement component is necessary. Two different reinforcement materials, viscose and high-temperature thermomechanical pulp (HT-TMP), were used through two different processes.

Viscose-PLA composites were fabricated by thermopressing commercial nonwoven composed of 35% PLA and 65% viscose, fabric weight 40-55 g/m2. Different parameters, such as layer quantities, temperature, heating durations and surface patterns, were varied. Composites with HT-TMP were produced by laminating handsheets of HT-TMP between layers of 100% PLA nonwoven, fabric weight 20 g/m2. These laminated sheets were further pressed into different shapes by using heat. Both nonwovens are produced by Suominen Nonwovens Ltd. Nonwovens and HT-TMP fibres were dyed with commercial reactive dyes. Testing different thermopressing parameters, layer thicknesses and mould patterns revealed a range of visual and tactile qualities, and gave ideas for potential applications and further experiments.

Potential applications

Through thermoforming it would be possible to create objects with both small-scale and large-scale structure to manufacture for example furniture and other interior objects. The visual appearance, tactile quality and technical properties of the material can be varied for example by colourisation of fibres, shapes of the moulds, amount of pressure and heat and the ratio between the biopolymer and cellulose fibres. This means that there is great versatility of different applications.


Varied foam-formed
non-wovens from the
same viscose fibre type

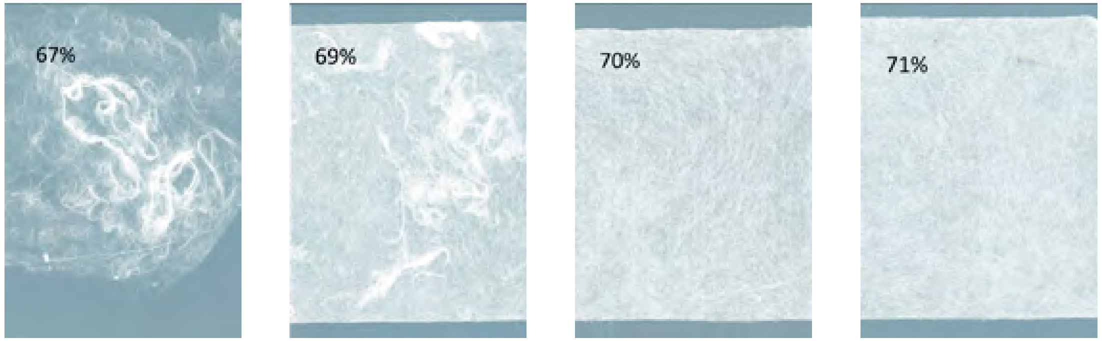


FOAM FORMING OF LONG FIBRES

Jukka Ketoja, Jani Lehmonen, Atsushi Tanaka, Ali Harlin, **VTT**

Background

The production of novel fashion and technical textiles requires the handling of long fibres in the process. Such fibres flock easily deteriorating the structural homogeneity. Foam forming enables the use of much longer fibres than those in water forming processes.



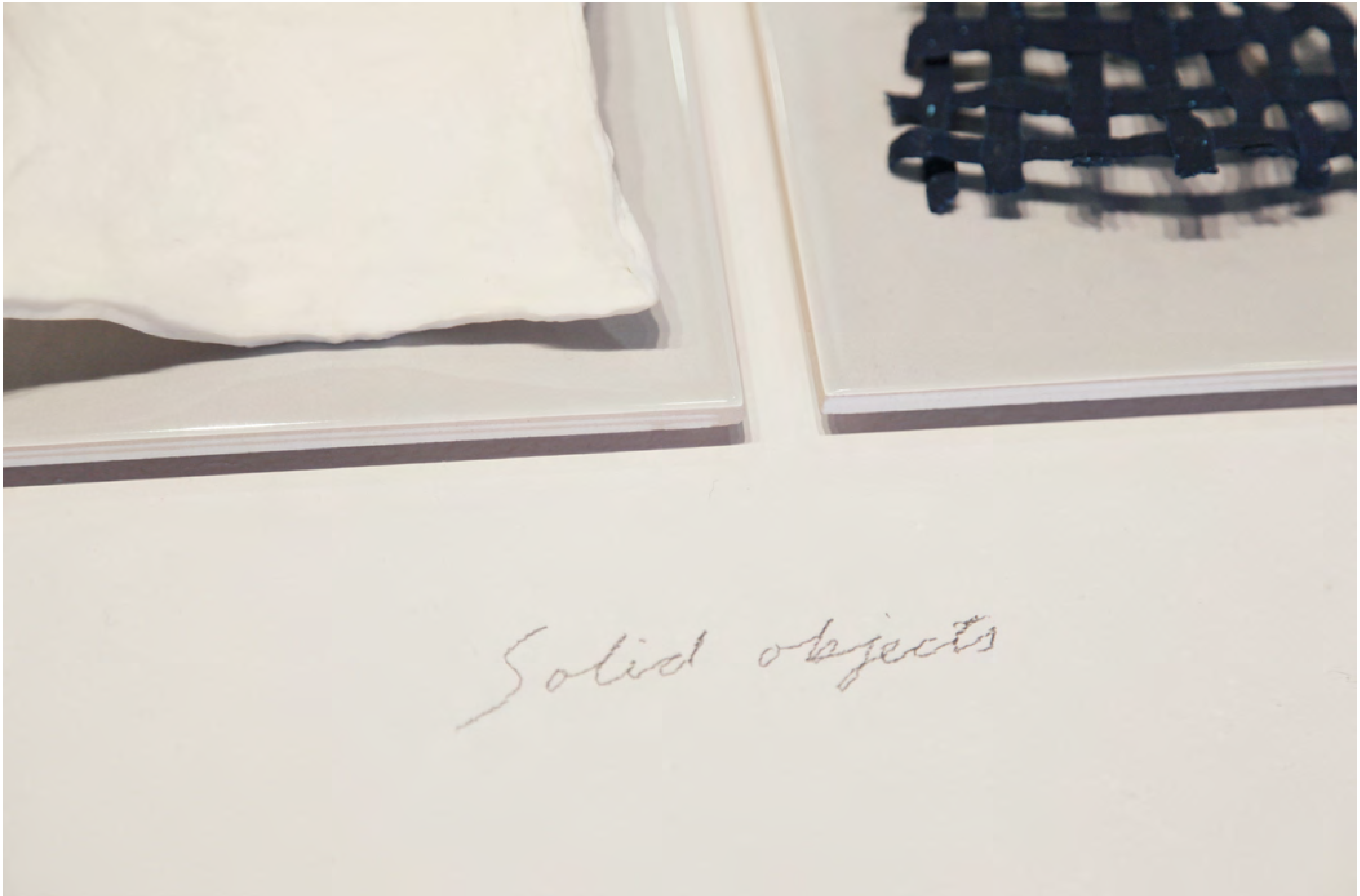
Characteristics

Foam properties and pre-processing and forming procedures have a central role for the flocking tendency and the homogeneity of the final structure. Critical process parameters have been determined by quantitative characterization of small-scale textile samples with model viscose fibres.

Potential applications

The study has led to a new modified pre-processing and forming concept in laboratory scale. The fundamental findings help in upscaling the process to the pilot scale. Versatile foam forming process is suitable for producing a wide range of tailored nonwoven materials based on cellulose raw materials.

Tekes VTT TAMPERE UNIVERSITY OF TECHNOLOGY Aalto-yliopisto

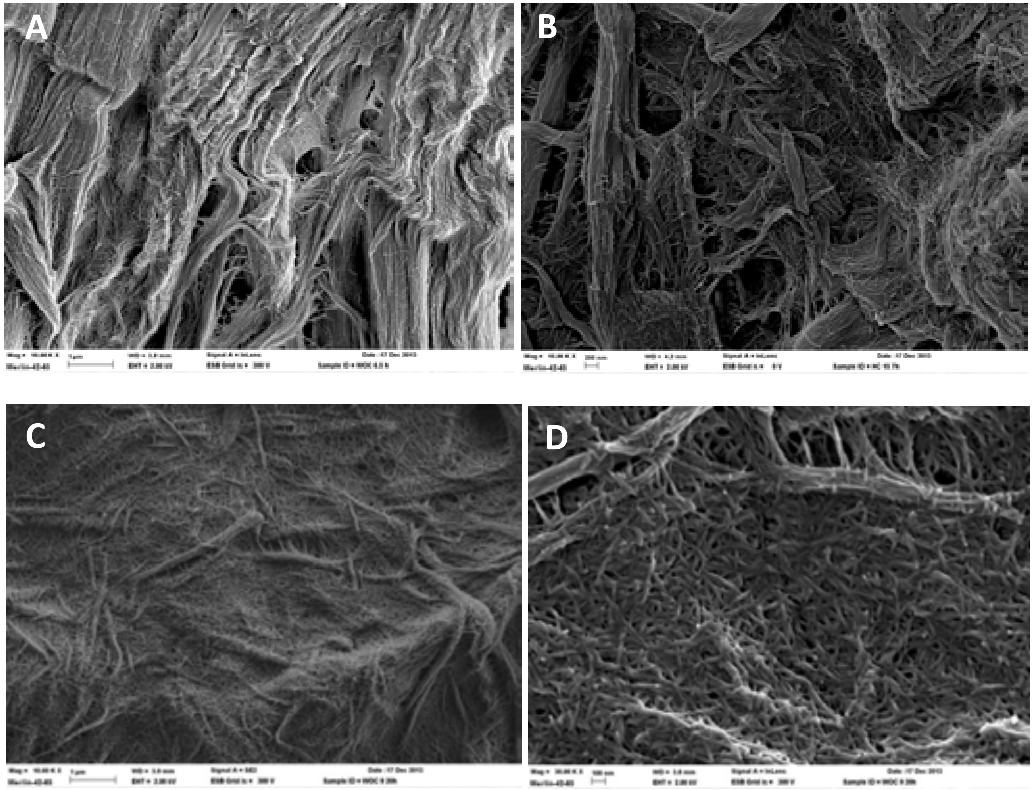

Solid objects

PRODUCTION OF SOLID OBJECTS FROM ENZYMATICALLY FIBRILLATED CELLULOSE MATERIAL

Jaakko Pere, Tuomas Hänninen**, VTT**

Background

Tailored Trichoderma reesei cellulases and swollenin were used to modify wood pulps suitable for further processing. High consistency mixing of softwood pulp with cellulases resulted to swelling and intense fibrillation. The degree of cell wall swelling and fibrillation could be controlled by the treatment conditions and enzyme dosage. Enriched cellobiohydrolase was superior to unravel and fibrillate softwood fibres terminating ultimately in nanosized fibrils during prolonged treatment. Such fibrillated cellulose could be used as a starting material for machineable solid objects.



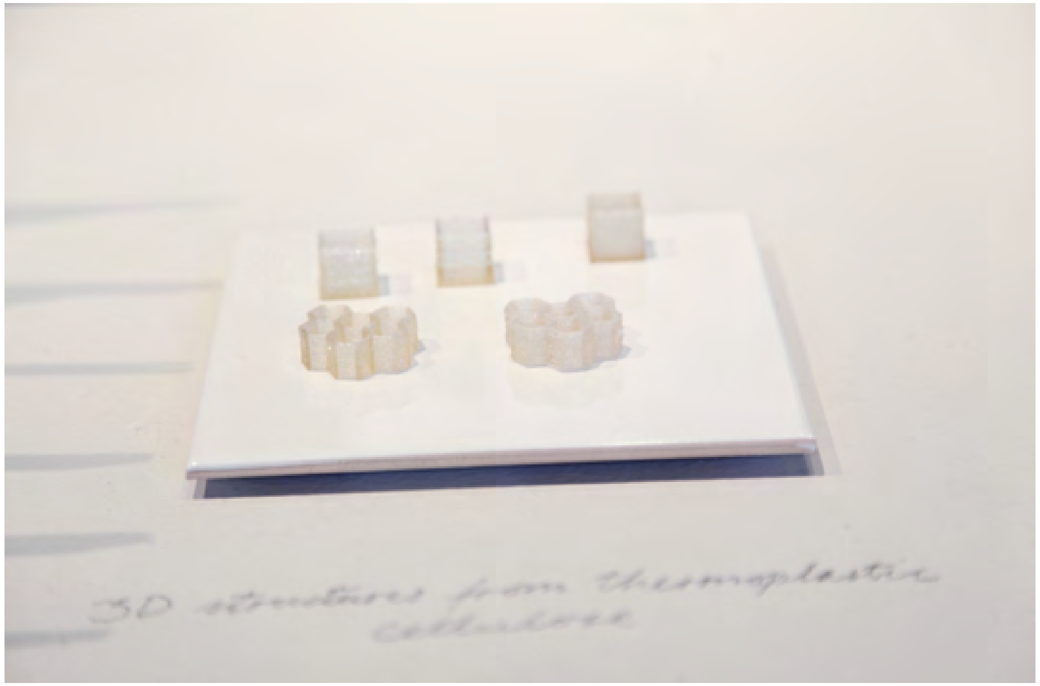
SEM images of fibrillated bleached softwood fiber after treatment of 7 hours (A-B) and 20 hours (C-D) with EcoPulp Energy

Characteristics

Fibrillated cellulose can be used to prepare dried objects with very interesting properties. The drying of fibrillated cellulose in oven results to a solid block, which can be easily machined to a desired shape with high precision. In dried form its bending strength is similar to certain plastics and therefore it can be used as substitute for man-made materials.

Potential applications

Solid objects have strength properties similar to certain plastics, and might be thus used as substitute for man-made polymers. Since the dried material is also precisely machineable, there exist several potential applications. Possible applications might therefore include e.g. consumer sports products, medical scaffolds, components in electronics and components in even industrial appliances. The solid cellulose material could possibly also be recycled after use, enabling more sustainable solutions, especially if applied together with other cellulose-based components resulting to all-cellulose products.



3D PRINTING OF THERMOPLASTIC CELLULOSE DERIVATIVES

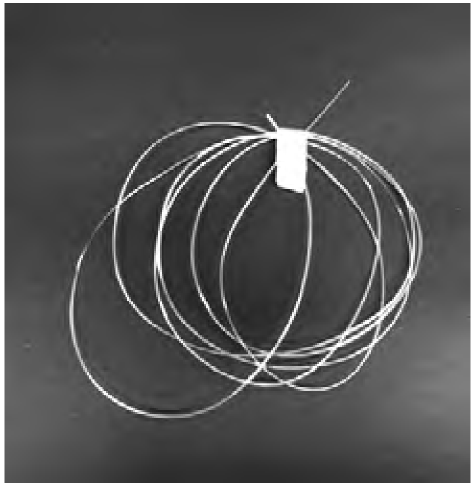
Arto Salminen, Jukka Seppälä, **Aalto University**

Background

Model design is an essential part in all 3D methods, and therefore 3D printing is ideal for tailoring small batches of personified products in a flexible and economical way. 3D printing entails a group of technologies which build up three-dimensional structures via layered deposition of metal powders, reactive monomers, thermoplastic polymers and other raw materials. Among different 3D technologies, Fused Deposition Modeling (FDM) is the most common technique in household printers. 3D FDM printers use thermoplastic polymers as raw material and the market is largely dominated by two plastics; ABS and PLA. To broaden the selection of renewable materials and investigate the suitability of cellulose-based raw materials in 3D printing, we have studied the 3D FDM printing of thermoplastic cellulose derivatives.

Characteristics

Thermoplastic cellulose derivative with low processing temperature was selected for the 3D printing trials. The pure cellulose derivative performs poorly during 3D printing due to insufficient layer adhesion. The performance of the material was improved through plasticization, which reduced melt viscosity and lower glass transition temperature. The plasticization improved the layer adhesion and overall performance during 3D FDM printing, thus enabling 3D structures from the thermoplastic cellulose derivative.



Potential applications

The flexibility of 3D FDM technology allows manufacturing of a variety of small volume products that are tailored and customized for individual needs. 3D FDM technology is mainly used to manufacture three-dimensional objects and the potential applications can be décor items and utensils. The method is also suitable for making more two-dimensional objects, such as plates and lithopane panels applicable in décor and advertisement applications. Regenerating the 3D objects via hydrolysis can be a route to controlled all-cellulose structures that have potential use in medical devices.

3D PRINTING OF CELLULOSIC PASTE MATERIALS WITH DIRECT WRITE –METHOD

Tiia-Maria Tenhunen, Tuomas Hänninen, **VTT**
Marjaana Tanttu, **Aalto University**

Background

In recent years 3D printing has become increasingly popular manufacturing method for customized products and small patches. The materials used for printing have traditionally been synthetic polymers, which have raised a concern about filling up the world with even more plastic waste. This has led to a demand to develop biobased printing materials for 3D printing, and for that, wood-based materials are excellent candidates. The material samples seen in the photos demonstrate a series of concepts focused on functional patterning for sports textiles. They were designed as a part of Master's thesis in Textile Art and Design, in Aalto University School of Arts, Design and Architecture. Collaboration between the research group and a textile student enabled ideation and exploration of possible applications, such as integrating support to clothing through multiple layers of printed patterns.

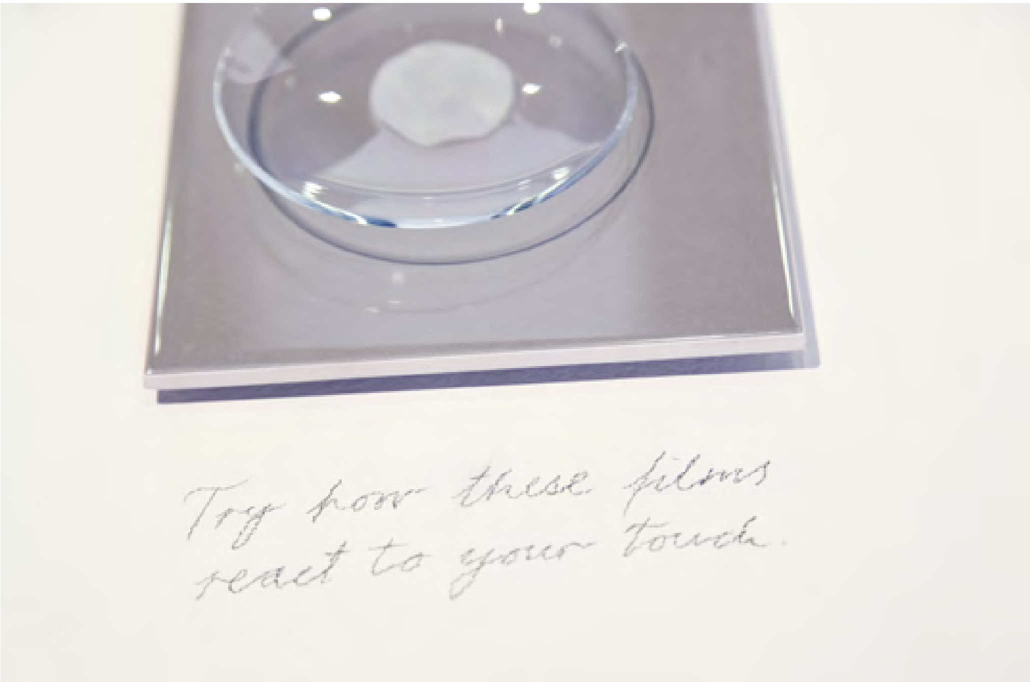
Characteristics

In this work the potential for cellulose-based materials for 3D- printing were tested as self-standing objects, printed surface structures on fabrics and other substrates. nScrypt direct-write 3D-printing method is an extrusion-based method for paste-like materials that uses a syringe pump system. Technique allows very different types of materials to be printed. Cellulosic materials used in this project included hydrogels, cellulose based plastics and pulp fibre composites. Cellulosic hydrogel structures can be printed using cellulose dissolved in ionic liquids with subsequent regeneration or by using highly hydrophilic oxidized nanocellulose. Structures can be stored in aqueous or highly humid conditions. Alternatively hydrogel structures can be used to produce highly porous aerogel-like structures by freeze drying. Hard cellulose derivative can be printed in very high dry matter content and dried very quickly in air with small shrinkage. Soft cellulose derivative forms flexible structures which are ideal for printing on fabrics. Pulp fibres and colorants can be mixed with soft and hard cellulose derivatives in order to create fibrous composite materials with completely different look and feel properties.

Potential applications

Possibility to use several kinds of cellulosic material for printing makes Direct-write technique applicable in various applications. The printed structures can be hard or soft, strong or brittle, stiff or flexible, porous or dense. They can be printed directly on substrates or fabrics or they can be self-standing structures. Objects can be large or assembled from several smaller parts or they can be microscopic surface structures with targeted surface functionalities. Possible applications can be found from medical science to personalized sportswear. The printed textile samples demonstrate added functionalities into sportswear. Hard cellulose derivative has been used to form stiff patterning in order to add structure to the fabric. Soft cellulose derivative was used as string of pearls to demonstrate grip effect. Cellulose fibres (10%) were added to soft cellulose derivative to create nice look and feel.


Nanocellulose film
reinforced with tri-
axially woven fibre
filaments.



RAPID, REVERSIBLE, VAPOUR-DRIVEN CURLING OF NANOCELLULOSE FILMS

Miao Wang, Xuelin Tian, Robin Ras, Olli Ikkala, **Aalto University**

Backround

Cellulose is considered to be the most abundant organic compound derived from biomass. Our material is made of nano fibrillated cellulose. The nano cellulose is prepared from native birch pulp and it has passed 12 times through a high-pressure homogenizer, during which the micro scale fibers are mechanically separated to nano scale. This nanoscale fibre has excellent mechanical properties, high specific area, low coefficient of thermal expansion, etc. This makes them suitable for producing films, composites, and foam materials.

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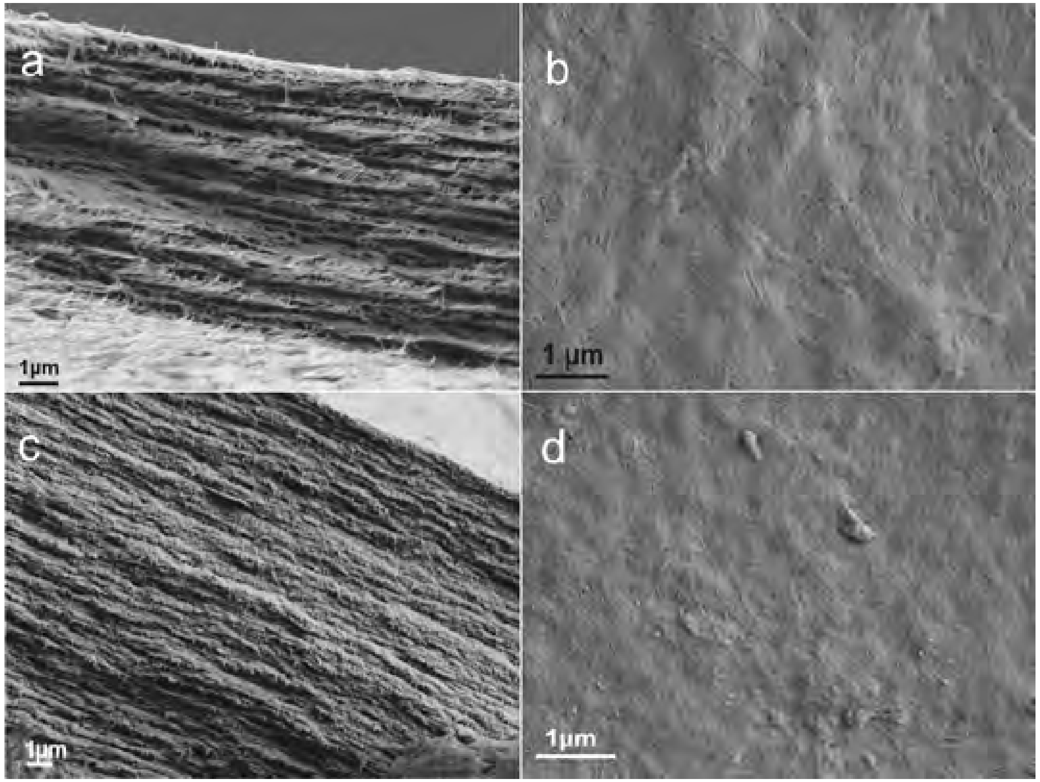
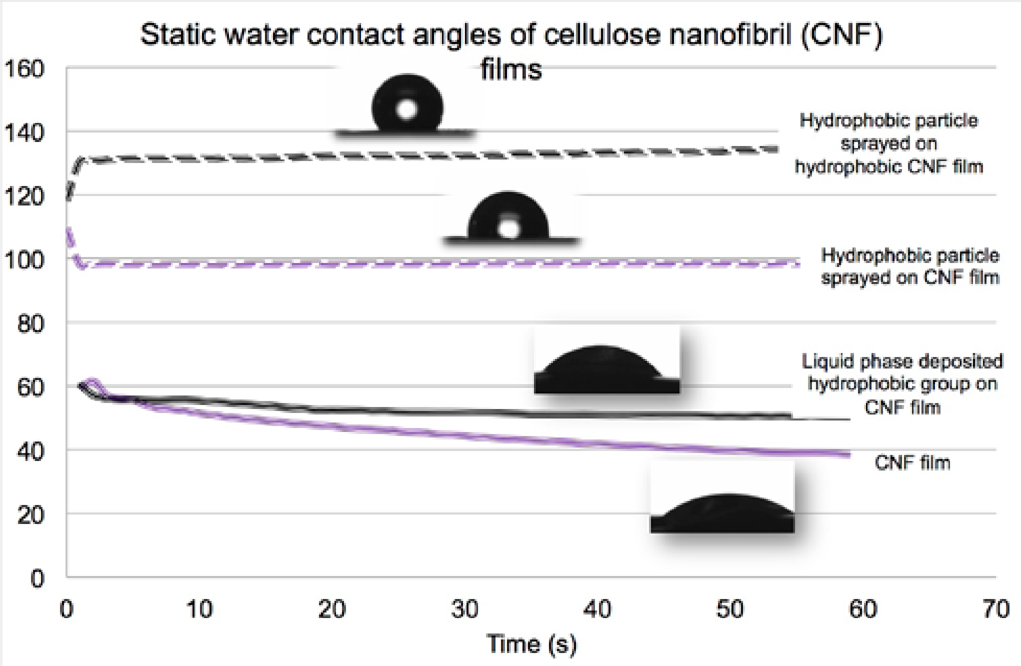


Characteristics

We use a vacuum filtration process to make high transparency nano cellulose film. The film is robust, flexible and has high sensitivity to humidity because of their hydrophilic characteristics. We found that this nano cellulose film has on-demand, reversible and highly sensitive deflection that responds to change of humidity.

Potential applications

The deflection properties of the nano cellulose film offer a promising route to design stimuli-response devices, e.g. humidity sensors or actuators, or walking devices, or moisture-carrying objects.



CELLULOSE-BASED SUPERHYDROPHOBIC SURFACES

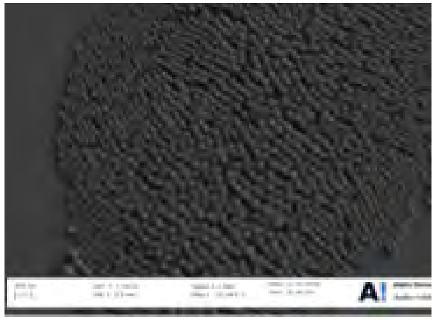
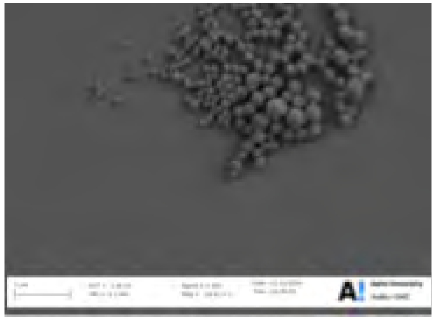
Pegah Khanjani, Tommi Huhtamäki, Mauri Kostiainen,
Jukka Itälä, Robin H. A. Ras, **Aalto University**
Maria Soledad Peresin, Tekla Tammelin, **VTT**

Background

Many plant leaves, such as Lotus, are always clean and have an extreme tendency to repel water and dirt. Such surfaces are superhydrophobic and characterized by high contact angle and low roll-off angle, and require a micronscale or nanoscale roughness combined with suitable hydrophobic chemistry. There is a need to prepare cheap and sustainable synthetic superhydrophobic coatings, and here we explore such coatings using cellulose as a basis material.

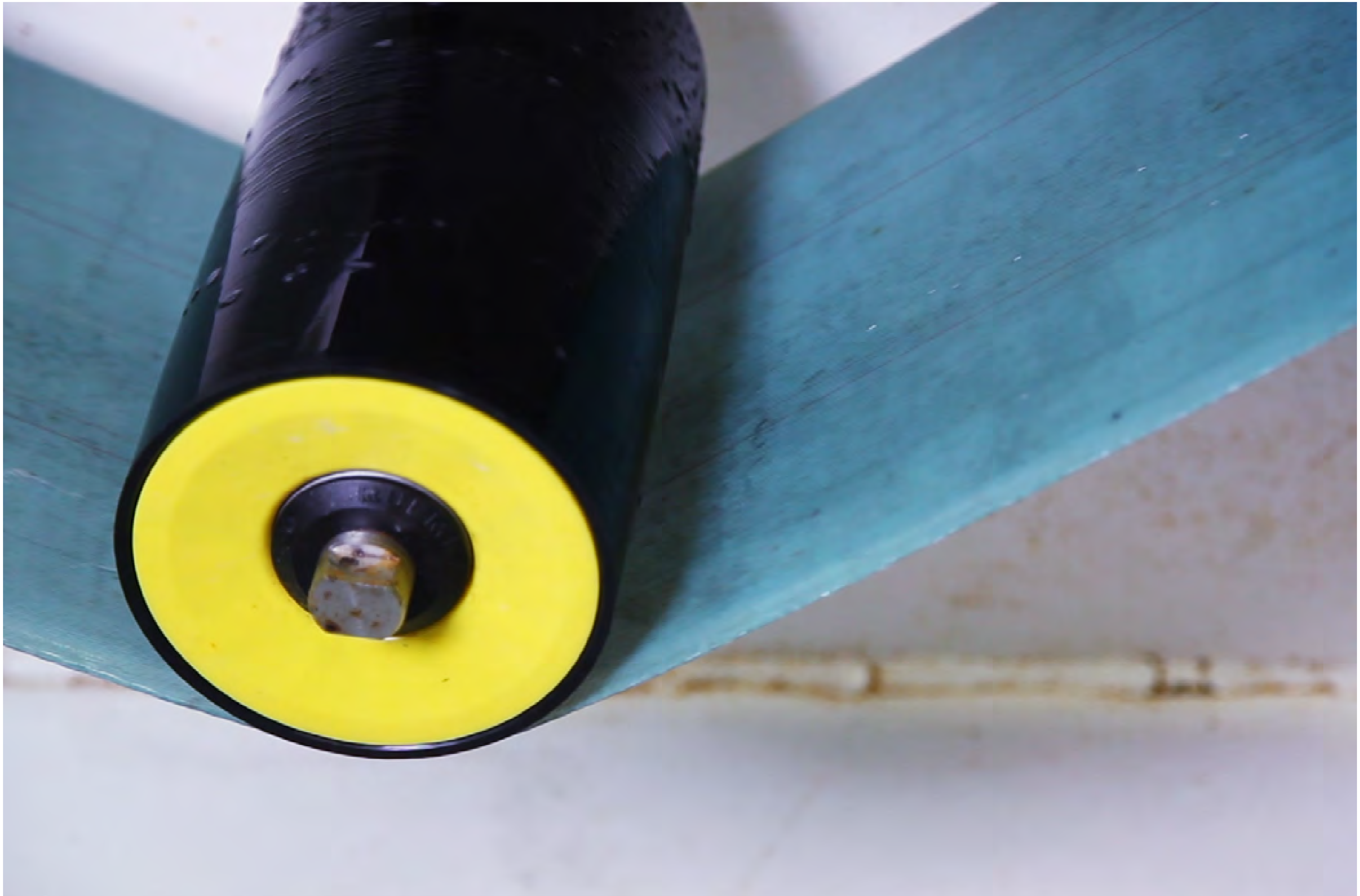
Characteristics

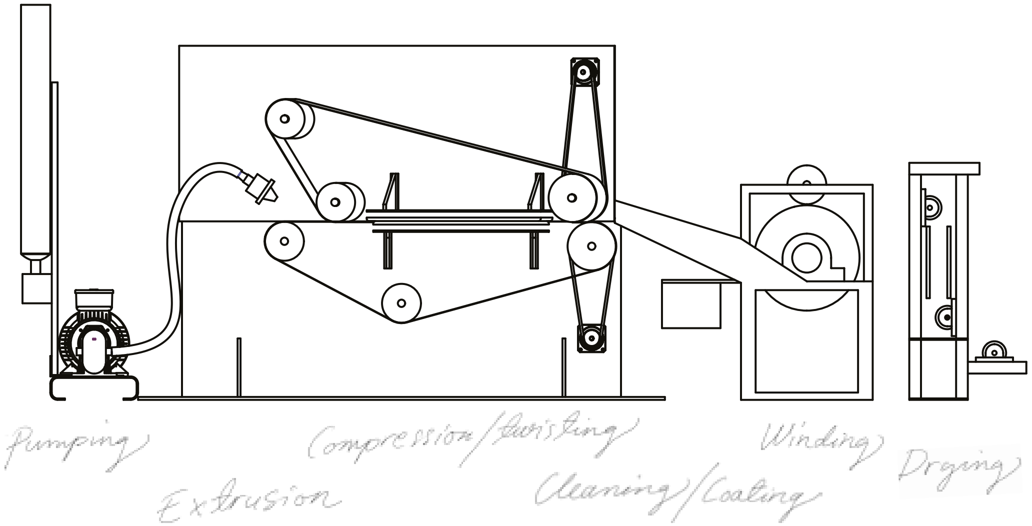
Fluorinated cellulose ester was obtained via esterification of cellulose nanocrystals (CNCs), and spherical nanoparticles of these fluorinated cellulose esters were obtained by a nanoprecipitation technique. The nanoparticles were deposited on a range of nanocellulosic film substrates with varying surface modifications, as to affect the adhesion and coating quality of nanoparticles to substrate. Our initial results show that very hydrophobic coatings were obtained.

Potential applications

Every surface attracts dirt, and cellulose-based surfaces typically get wet when in contact with water. Superhydrophobic surfaces could find applications in dirt-repellency, they stay always dry, reduce ice adhesion and reduce fogging. They may find uses as packaging material, textiles, outdoor clothing and trekking gear, windshields, construction material and more.





NOVEL MACHINERY FOR CELLULOSE PRODUCT MANUFACTURING

Ville Klar, Petri Kuosmanen,Thomas Widmaier, **Aalto University**
Johanna Liukkonen, Juha Salmela, Ali Harlin, **VTT**

Background

The Aalto School of Engineering is participating in the development cellulose yarn production by researching new production machinery. Currently, the research carried out at the Department of Engineering Design and Production is focused on continuous yarn production utilizing a wet spinning method. In this method, alginate cross-linking is used to produce the initial wet yarn which is then twisted and dried to produce a thin and strong yarn. This approach has been developed at VTT, where the yarn properties and chemistry of this technique have been studied in detail.
The research consists of the design and testing of yarn production machinery. The yarn manufacturing process involves extruding, twisting, drying and winding steps. Further steps of coating and cleaning are being researched. The goal is to design easily scalable machinery with control over process parameters that affect the yarn characteristics.

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Characteristics

The first prototype is capable of continuous yarn production with control over important process parameters at each step. Fibre orientation can be managed with the extrusion parameters and twisting of the semi-formed yarn can be adjusted. Furthermore, compression, drying and winding can be controlled. All of these parameters have a significant impact on the yarn properties.

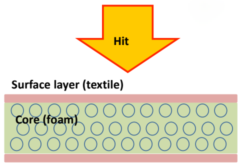
The prototype is capable of yarn speeds of up to 10 m/s. As the dewatering of the yarn already occurs to a great extent at the twisting stage, the drying does not require much energy. Sufficient drying is achieved with a heated roll in combination with IR emitters.

Potential applications

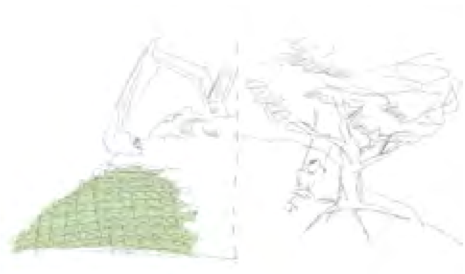
The applications of a sustainably produced high quality bio-friendly yarn are practically endless. With control over fibre orientation and other important yarn attributes, different yarns can be designed to suit specific purposes ranging from composites to textiles.

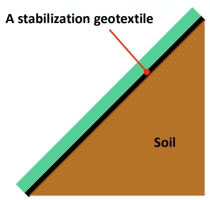
Cellulose fibre yarn has the potential of becoming as ubiquitous in the textile industry as cotton. It is a far more environmentally sustainable alternative. Forming pulp into different products is an area of high skill in Finland. The future industry can be built on decades of experience and expertise.

As the yarn formation is researched further, doors open to new materials. A student-driven project has just been launched to develop a method to produce cellulose bio mesh with the alginate cross-linking approach.



Possible uses of cellulose in SportTech application area include e.g. shock absorber and a breathability layer in shoes and helmets: similar materials can be used also in heat insulator in the sleeping bags, and core material in the composites and sportswear.





Biodegradability of cellulose can be utilized in geotextile (GeoTech) which decomposes with time when vegetation grows and stabilization is not needed anymore.

UTILIZATION OF CELLULOSE IN TECHNICAL TEXTILES AND COMPOSITES

Arja Puolakka, Sanna Siljander, Tomi Hakala, **Tampere University of Technology**
Ali Harlin, Pirjo Heikkilä, **VTT**

In technical textile applications function is more important than aesthetics. Application areas of technical textiles include, for example, materials used in industry (InduTech) such as filters and absorption textiles and wiping products, and in agroculture (AgroTech) including fibre materials used in horticulture, forestry and fishing. Form of technical textile products vary widely from fabrics and nets to ropes and hoses. Textile materials can also be used as composite reinforcement - as staple or continuous fibres; as sheet materials such as woven, knitted, braided and nonwoven structures; and as 3D textiles.

Technical textiles and composite areas utilize lot of synthetic fibres, but there are many applications were cellulose have advantages over them. Inherent properties of cellulose which can be utilized in selected technical application areas include, for example, absorption, bio-degradability and non-toxicity, light weight, and good hand&feel properties. Mechanical properties of cellulose are also sufficient for many non-load bearing applications.

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Figure 1. Application areas of technical textiles according to classification developed by Techtextil, Messe Frankfurt Exhibition GmbH

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In transportation (MobilTech) possible applications for cellulose include composite and textile products used e.g. insulating materials for cabins (noise, heat, odour), air and oil filters and interior decoration (carpets, seat covers, panels and mats).

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Possible products for cellulose in BuildTech area include sound and heat insulation (walls, pipes, etc.), temporary protection elements (fences, radiation shields, etc.), internal & movable wall elements, beams, and pillars.

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Medical applications (MedTech) for cellulose can include wound dressings and bandages, face masks, gowns and sheets, support stockings, sutures, absorption materials, towels, as well as personally moulded, comfortable, and aesthetic orthopaedics.

Designer **Heidin Wikar** Photography **Christian Jakowleff**

BRANDING

Could Finnish cellulose be branded? Who would be the brand owner(s)? This subject was explored and discussed throughout the project, but the branding exercise itself was transferred to the second phase of DWoC. The branding of cellulose-derived design products could be on different levels. The Finnish cellulose knowhow and network could be branded, the raw material (e.g. birch or highly appreciated long-fibre softwood pulp) or new cellulose-based materials could be branded according to their industrial applications, and each designed end-product using the materials could be the focus of branding work. Branding is en essential element of any business concept and has to be considered whenever starting new businesses, but there seems to be also a demand for generic cellulose-related brands in Finland.

Activities Aiming at Novel Products & Business

FIBIC

FIBIC turns research and science into sustainable bio-based solutions

Finnish Bioeconomy Cluster FIBIC is one of six Strategic Centers for science, technology and innovation in Finland (SHOK). The SHOKs offer businesses and research organizations a new way of engaging in close, long-term cooperation and leveraging the best competences and resources.

The research programmes are the core of the FIBIC activities. Through the programmes the aim of FIBIC is to combine research and companies for innovative solutions which accelerate Finland to become a pioneer in the sustainable bioeconomy.

FIBIC has launched a research program called Advanced Cellulose to Novel Products (ACel) in 2014. The programme addresses the opportunity which is created by the fact that the use of materials – using sustainable renewable raw materials - is growing globally. This is done by utilizing the world leading cellulose competence in Finland.

The program targets three product areas: textile fibers, thermoformable materials and cationic chemicals. New materials for these applications are created through novel scientific methods looking at the cellulose reactivity, cellulose modification and modification processes over the whole value chain.

The program also aims to create a new concept for doing research together - the application research network for cellulose materials. The target is to facilitate the implementation of the research results during the course of the program.

The program has 9 companies and 6 research partners: Metsä Fibre, Stora Enso, Andritz, Roal, Kemira, Metsä Board, Nanso and Marimekko; Aalto University, Lappeenranta University, Oulu University, Åbo Akademi, Helsinki University and VTT.

Activities Aiming at Novel Products & Business

VTT

We help our customers to develop biobased products consistent with the sustainable development and to utilise the potential of fibre based processes.

VTT has decades of experience in understanding and treating the properties of fibres, and in the application of knowledge, all of which helps to renew the forest sector. We work in unique test environments where papermaking methods can be used to develop completely new kinds of materials and products. Our product portfolio for industrial applications contains among others the use of foam forming, foam coating and nano- and microcellulose in fibrebased products. We are active in developing biocomposite products and flexible structures and films. Our knowledge in cellulose includes also dissolving pulp and cellulose carbamate materials. We have, for examples, produced textile fibres and nonwovens using recycled card board as raw material.

VTT has testing equipment suitable for the needs of the renewable forest sector, from the laboratory right through to pilot scale.

ForestTech serves corporate customers online

By accessing our free online service you will be first to know of any breakthroughs in our R&D, as well as receiving the latest news and a chance to get your hands on the project ideas of the future. You can also explore the full range of VTT technologies.

Get to know the ForestTech website **http://www.foresttech.fi**

One example of projects:

Wood-based thermal insulation materials (WoTIM, www.wotim.eu). In this project, superior cellulose based insulation materials are developed. The target is that the performance of the novel cellulosic insulation materials is at comparable level with the materials made of polyurethane foams.
Five partners are involved in the WoTIM project: VTT (coordinator, Finland), Innventia (Sweden), FCBA (France), Holmen (Sweden) and Soprema (France). In addition, there are four cofounding companies: Stora Enso, Ekovilla Oy, Neovo Solutions Oy and Oy Interenergy Pressocenter Ltd. The project started in January 2014 and will be concluded in December 2016.

Activities Aiming at Novel Products & Business

Aalto University

Materials research and Design are two of the four recognized strong points of Aalto University. The wide spectrum of expertise in materials sciences at Aalto University offers extensive opportunities for new kinds of collaboration. Materials science research is carried out in all four schools of technology (CHEM, SCI, ELEC, ENG). The research areas include nanotechnology, microfabrication and biomaterials, as well as advanced functional materials. At the School of Arts, Design and Architecture one of the emerging areas of design research competence is sustainable design. It includes sustainable use of materials, the impact of design on sustainable consumption and the processes and approaches supporting the creation of sustainable product service systems.

The multidisciplinary research environment of Aalto University offers brand new opportunities for the interaction of design research and other disciplines. Combining design and cellulose research has been on-going ever since the Aalto University was established. Currently several activities including CHEMARTS-collaboration and research projects like Design Driven Value Chains in the World of Cellulose and FIBICs Acel -project continue the successful work. Current projects include, e.g., biomimetic nanocomposites based on nanofibrillated cellulose or cellulose nanocrystals, functional materials from cellulosic substrates manufactured from 2D constructions, such as sensors and optoelectronic devices.

Activities Aiming at Novel Products & Business

Tampere University of Technology

Department of Materials Science:

Fibre Materials: The research work focus on enzymatic assisted dissolving of cellulose and processing of cellulose solution into fibers and films by wet spinning technology (Biocelsol process). Enzymatic treatment enhances the dissolution of cellulose and it dissolves without any harmful chemicals (e.g. carbon disulfide). The regenerated products can be utilized e.g. in medical purposes. The fibres are also suitable for textile processes, e.g. non-wovens, spun yarns, and knitted fabrics.

Paper Converting and Packaging: The research work focus on nanostructures, thin coatings, materials from renewable sources and biodegradable packaging materials. Extrusion and dispersion coatings, lamination and cast film techniques as well as novel materials and structures for packaging can be developed with the pilot-lines. Material characterization of package materials includes e.g. barrier properties, heat sealability, surface energy and adhesion.

Plastics and Elastomer Technology: The Luoma –project (Luonnonmateriaalien mahdollisuudet polymeerimatriiseissa, Possibilities of natural materials in polymer matrices) focuses on the reinforcing of thermoplastics with several natural materials, e.g. flax and kraft pulp. The products have been manufactured by melt mixing of shredded pulp and plastics in the extruder. Cellulose fibers strengthen and stiffen plastics but the impact strength decreases.

Department of Automation Science and Engineering:

Research areas:
Mechanical properties of wood material in fiber level under industrial defibration circumstances. Energy efficient mechanical nano/micro fibrillation of cellulose. Non-toxic nano/micro cellulose can be used e.g. as adhesive or binder.Characterization of 3D structure of paper and corresponding fibrous materials with the developed image analysis.The developing of microrobotic technique to measure individual cellulose fibers and fiber-fiber bonding for quality control, characterization of mechanical and chemical treatments of fibers,

and **Department of Chemistry and Bioengineering**:

Supramolecular Photochemistry: Porous thin films made from cellulose have nanoscale structure and thus very high surface area. Films can be used for the manufacturing of electrodes, and further in solar cells.

CONCLUSIONS

The multidisciplinary **DWoC**- team has been testing how design and materials research can collaborate in practice.Common language has been created to combine the different disciplines and non-conventional working methods have been applied. New sustainable product concepts and product-service systems have been explored by combination of design-driven prototyping to hypothesis driven technology development. Several very promising technologies ranging from manufacture of fibre yarn from pulp or nanocellulose or production of novel cellulosic composite structures. Designers have explored cellulose material properties by prototyping, using iterative process together with the technologists. The DWoC design team created new visual concept for documenting and exhibiting the results of material research for multifaceted audiences.

The DWoC project has been able to raise the interest towards cellulose and to boost design driven paradigm change to the forest industry.

Aalto University

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