WWSC

WALLENBERG WOOD SCIENCE CENTER

Wood nanotechnology – new materials from trees

Annual report 2023

KTH VETENSKAP OCH KONST

CHALMERS

LiU LINKÖPINGS UNIVERSITET

TREESEARCH

Knut och Alice Wallenbergs Stiftelse

Table of contents

Wallenberg Wood Science Center

Wallenberg Wood Science Center (WWSC) was first launched in 2009 as a collaboration between KTH Royal Institute of Technology (KTH) and Chalmers University of Technology (Chalmers), eventually also with participating researchers from Stockholm University (SU), Luleå Technical University (LTU) and Umeå University (UmU). The second phase of WWSC was launched in January 2019 and also brought about that the Laboratory of Organic Electronics (LOE) at Linköping University (LiU) became a center member. As of the end of 2023, more than 90 PhDs have completed their doctoral training within the framework of the center. According to the Web of Science (2024-05-05), the affiliations "Wallenberg Wood Science Center", "Wallenberg Wood Science Centre", or "WWSC" have gathered 42 416 citations, 39 132 without self-citations. The center's h-index is 93. Currently, (December 2023), the center engages ~70 faculty members/researchers, ~10 postdocs and ~60 PhD students.

The research in the center has a focus on new materials from trees. The aim of WWSC is to create knowledge and build competence that has the potential to form the basis for an innovative future value creation from forest raw materials by developing methods and processes that provide molecular and structural control. The scientific activities have two main objectives; the first is on fundamental understanding of wood tissue, wood fibers, cellulose, hemicelluloses, lignin and related components, including bio-based polymers. This includes extraction, disintegration, purification processes and their mechanisms, characterization of biomolecules, nanocelluloses, fibers, colloids etc., as well as novel modification routes and biopolymer synthesis. The second objective is new material concepts, where the wood material components (fibrils, fibers, wood veneer, lignin polymers, wood-based colloids etc.) are combined with other constituents and assembled into materials and devices. Research activities in WWSC span broadly from refining of wood and wood components, via extraction/fractionation of biopolymers and other constituents in wood to the utilization of wood polymers and other constituents in advanced nanotechnological devices with potential use in energy applications or electronics.

WWSC 2023

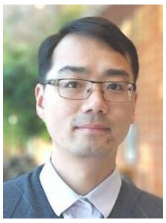
2023 was a transition year for WWSC in several respects. A large number of PhD students successfully defended their theses. Most of the dissertation seminars are still available on the WWSC webpage and constitute a very rich source of new knowledge (https://wwsc.se/wwsc-defense-of-doctoral-theses-online/). It will be exciting to follow the newly graduated PhDs in their new careers. During the WWSC Summer Workshop, which was held at Sånga-Säby, Ekerö in June, there was an official diploma ceremony, awarding all of those who fulfilled the WWSC Academy requirements during the past years (even though not everybody could participate in person).

During 2022, many new positions were opened and the start of 2023 brought intense evaluation, interviewing and selection to finally result in a new batch of PhD students and postdocs. No regular WWSC Academy courses were organized during 2023 but a "get-to-know-each- other" activity was organized in October as an introduction to the WWSC ways of working and the WWSC community. Both representatives from industry and alumni participated.

WWSC has also contributed to the recruitment of five new assistant professors at KTH, Chalmers and Linköping University which all are warmly welcome to WWSC. At the WWSC Winter Workshop, which was held at Bohusgården, Uddevalla in November, the new assistant professors presented themselves and their research activities to the WWSC community.

Alexander Grötsch
Assist. Professor, Applied Mechanics and Physics, KTH Royal Institute of Technology

Amparo Jimenez Quero
Assist. Professor, Industrial Biotechnology, Life Sciences, Chalmers University of Technology

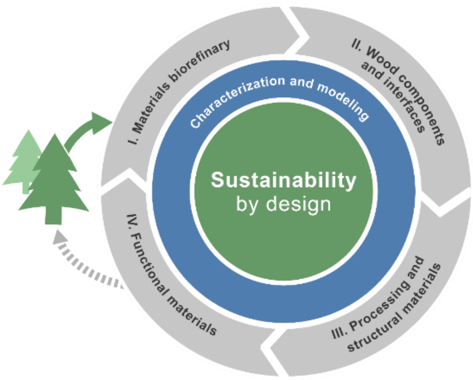


Liyang Liu
Assist. Professor, Chemical Eng., Chemistry and Chemical Eng., Chalmers University of Technology

Peter Olsén
Assist. Professor, Dept. of Science and Technology, LOE, Linköping University

Alexander Holm
Assist. Professor, Dept. of Science and Technology, LOE, Linköping University

During the year, WWSC gradually shifted towards a new organizational scheme, even though the previous and the new program structures have run in parallel.



Program I – **Materials biorefinery** (led by Assoc. Profs. Merima Hasani and Johan Larsbrink, Chalmers)

Program II – **Wood components and Interfaces** (led by Profs. Eva Malmström and Lars Wågberg, KTH)

Program III – **Processing and structural materials** (led by Prof. Daniel Söderberg and Assist. Prof. Yuanyuan Li).

Program IV – **Functional materials** (led by Profs. Mats Fahlman and Isak Engquist, LiU).

The work in the Program I aim at providing structural and processing knowledge required to enable highly selective and material efficient decoupling of the forest biomass with structure and functionality control. The program approach relies on gaining a deep mechanistic understanding of the decoupling processes whether pertaining to the processability behavior of the biomass components or their structural conversions associated with applications. With resource efficiency in biomass utilization as a priority, a particular focus is placed on recovery and upgrading of underutilized and waste resources, ranging from hemicelluloses and bark to sludge generated in pulp mills.

Program II aims at acquiring deeper knowledge regarding lignin, hemicellulose, small molecules and modifications thereof in an effort to pave the way for wood-based bioplastics, coatings, adhesives, and property-enhancing additives as well as tailored polymers for interfacial engineering. Further, biomimetic and synthetic approaches for engineering of surface properties will be investigated since interfacial adhesion between components is of utmost importance, both to accomplish durable, as well as recyclable/reusable materials. An overarching goal is to develop materials or material additives that can support a decreased dependence of fossil-based materials, and hence to accelerate the transition into circular materials.

Program III targets a broad range of activities centred around the innovative processing and characterisation of wood-based materials and techniques for sustainable energy solutions, additive manufacturing, and composite structures.

Program IV includes an array of actions aiming at combining functions and characteristics of forest biopolymers with the ditto of electronic and photonic materials, in an effort to derive technology platforms for many future applications. The aim is to explore and develop radically new material systems, devices, and systems of relevance for the areas of communication, energy technology, and even med-tech, at the same time complementing the technology of traditional high-tech and cellulose-based industry, targeting for instance future batteries, fuel cells, and self-cooling papers – to a large extent based on cellulose, nanocellulose, and lignin components.

Characterization and modelling are key to all research activities pursued in the center. Materials, in a broad sense, may bring a significant sustainability burden during extraction/isolation, processing, usage, and disposal. Throughout their lifecycle, materials may contribute to greenhouse gas emissions and/or waste. Additionally, their disposal can pollute land, water, and air. These challenges require sustainable material sourcing, efficient production methods, and innovative recycling technologies. Design for durability, recyclability, and biodegradability can mitigate environmental impacts, promoting a more sustainable future. These are all aspects that WWSC will consider in our four program areas (I-IV) during the years to come.

WWSC 2.0 Program 1: Wood components – extraction, characterization and properties

Active PIs

Chalmers: Prof Lisbeth Olsson, Program 1 responsible, Prof Hans Theliander, Prof Anette Larsson, Assoc Prof Johan Larsbrink, Prof Eva Olsson
KTH: Assoc Prof Olena Sevastyanova, Prof Martin Lawoko, Assoc Prof Lauren McKee, Prof Francisco Vilaplana
LiU: Prof Reverant Crispin

Overview of the activities within the program

Program 1 under WWSC 2.0 is in its final phase and during 2023 the following PhD students defended their thesis:

- Kenneth Arandia, Chalmers (Project 1.1.1a Fractionation of wood components using membrane filtration; https://research.chalmers.se/en/publication/538357)
- Roujin Ghaffari, Chalmers (Project 1.1.2a Mass transfer challenges in wood decomposition; https://research.chalmers.se/en/publication/537561)
- Andrea Seveso, Chalmers (Project 1.3.1a Enzyme discovery and structure-function investigation; https://research.chalmers.se/en/publication/537004)
- Monika Tolgo, Chalmers (Project 1.3.1b Enzyme discovery, fungal enzyme machinery as source for novel LPMO discovery and applications; https://research.chalmers.se/en/publication/534072)
- Maria Karlsson, KTH (Project 1.4.1a Lignin biorefining; extraction and characterization of reactive homogeneous lignins, DiVA, id: diva2:1754762)
- Ioanna Sapouna, KTH (Project 1.4.1b Native lignin structure, polymerization, and interaction with cell wall components; DiVA, id: diva2:1756366)

The activities performed during 2023 is shortly summarized below:

To develop the processing in a material biorefineries, separation and mass transfer was studies. The fluid dynamic gauge tool was further explored and used to gain better mechanistic understanding of the fouling behavior during cross-flow filtration. This knowledge is essential for the development of membrane separation processes for lignocellulose derived streams (Project 1.1.1a). Mass transfer studies in wood decomposition addressed both the lignin adsorption and transport and how ion effects influence these processes as well as studies of the impregnation of ionic liquids and lignin release (project 1.1.2a).

The discovery, characterization and application of several enzymes is part of several projects with the final aim of applying enzymes in decomposition or valorization of lignocellulose derived streams. Glucuronyl esterases can decouple lignin and carbohydrates and the diversity of glucuronyl esterases were investigated in detail. The characterization of the selected enzymes included their ability to cleave different bonds between lignin and carbohydrates (Project 1.3.1a). The enzyme group lyctic polysaccharide monooxygenases (LPMOs) cleave cellulose and hemicelluloses oxidatively. Novel activities have been shown on different kinds of xylans. Applications of LPMOs encompassed supplementation of LPMOs to enzyme cocktails that led to improved hydrolysis of mildly steam-pretreated spruce and functionalization of nanocrystalline cellulose by application of LPMOs to generate carboxyl groups that allowed cross-linking (Project 1.3.1.b). Galactose oxidases were an interesting enzyme group to investigate due to their potential to functionalise hemicellulose. Bacterial enzymes (from the AA5 family) were characterised in depth and were found to have unexpected activities on primarily alcohols rather than on carbohydrates (Project 1.3.3)

The structural changes following different pretreatment conditions and/or enzyme hydrolysis were studied by electron microscopy. Applying FIB-SEM allowed cross sections of the material that revealed the internal structure of differently pretreated spruce. Additional characteristics of the material were mapped using SAXS to gain information on the crystallinity. (Project 1.3.2.b).

Lignin is the subject in several projects, and reliable and rapid analytic tools to evaluate the lignin is an important part of the tool box together with different fractionation methods. A spectrometric based method was developed for rapid evaluation of total phenolic hydroxyl structures in lignin (project 1.2.1). For lignin biorefining, methods for extraction and analysis of well characterised structures were further developed and analytics were complemented with MALDI-Tof MS (Project 1.4.1.a). With help of spruce tissue cultures, the lignin synthesis in presence of hemicellulose was studied. Lignin extraction from birch and spruce was used to gain knowledge on the difference of these different lignin. Furthermore, it was studied how the difference influence the processing and the application of lignin in nanoparticles (project 1.4.1.b). To further understand the interaction between hemicelluloses and celluloses and lignin an integrated analytical and computational approach was used. The knowledge of the interactions has proven important to understand which is the optimal conditions for separation of the different wood polymers. In addition, the detailed composition of different hemicelluloses was mapped (Project 1.4.2).

Lignin has also been used in different applications. With the aim of exploring Zn-ion batteries as candidates for low cost and sustainable batteries, lignin-carbon electrodes have been developed, applying an “water-in-polymer-salt” electrolyte to improve the capacity (Project 1.2.2.a).

WWSC 2.0 Program 2: Biobased polymers and modelling

Active PIs

KTH: Prof Eva Malmström – Program 2 responsible, Prof Monica Ek, Prof István Furó, Prof Minna Hakkarainen, Prof Mats Johansson, Prof Martin Lawoko, Assoc Prof Lauren McKee, Prof Karin Odelius, Dr Linda Fogelström, Assoc Prof Per-Olof Syrén, Prof Francisco Vilaplana, Assoc Prof Jakob Wohlert
Chalmers: Prof Anette Larsson, Assoc Prof Giada Lo Re
LiU: Prof Mats Fahlman

Overview of the activities within the program

Program 2 is focusing on all biopolymers which can be isolated from wood except (nano)cellulose which is covered by Program 3, as well as on bio-based polymers attainable by polymerization of low molar mass extractables or degradation/fractionation products by sustainable methods, all in collaboration with Program 1.

Program 2 aims at:

- gaining fundamental understanding on why biopolymers are sensitive to humidity or water which may hamper their potential applicability in various material applications,

- designing new sustainable materials from bio-based raw materials using as benign chemistry as possible and green chemistry principles,

- elucidating the fate of cellulose- (biopolymer-) based materials at the end-of-life.

The rationale for the design of novel materials and the potential material applications are explored in collaborations with Programs 3–5. As Program 2 has developed, it is now obvious that several of the projects are aiming to develop a material that has a potential to substitute a fossil-based counterpart, or that can function as an additive to improve the properties of an already existing material. However, an overarching common denominator is the ambition to gain fundamental understanding from the nano (molecular) level to macroscopic properties.

In the domain of forest-based materials for optoelectronic devices, the research led by LiU researchers focuses on using industrial solvent-fractionated LignoBoost Kraft lignin (KL) as a binary cathode interface layer (CIL) in organic solar cells (OSCs). Their approach enhances OSC efficiency and stability while utilizing wood-based materials, paving the way for sustainable optoelectronics.

Another study investigates the use of hemicelluloses for wood adhesive applications, showing promising results for bonding wood surfaces. By optimizing formulations and understanding production parameters, hemicelluloses demonstrate potential for enhancing wood particleboards' properties.

In the realm of lignin applications, researchers explore lignin as a biopolymer for thermoplastics, demonstrating the feasibility of incorporating lignocellulose-based materials into commercial polyesters to enhance bio-based content and scalability. Additionally, the reinforcement mechanisms of lignin in polymer nanocomposites are investigated, shedding light on interface engineering for effective incorporation into thermoplastics. Further studies delve into lignin derivatives for polymers, highlighting the development of lignin-based thermoset resins and investigating the effect of lignin source on resin performance. Novel functionalization routes for technical lignin are explored, demonstrating enhanced thermoset properties and device stability in organic solar cells.

In the domain of synthesis of biobased materials, research is focused on synthesizing biobased and degradable latex nanoparticles using wood-based monomers, offering potential applications as surface modifiers on biofibre substrates. Additionally, efforts are directed towards developing thermoplastics and thermosets with divanillin as a core component, enabling repeated recycling and achieving properties matching conventional plastics.

Moreover, innovative approaches are explored for utilizing bark as a source of valuable materials, such as cellulose and lignin, through sustainable extraction techniques. These efforts contribute to eco-friendly solutions and the development of high-value products from side-stream resources.

Lastly, studies investigate the structure and dynamics of heterogeneous wood biopolymers, particularly xylan, revealing insights into the impact of chemical substitutions on the physical properties of the cell wall polymer matrix.

Overall, these research endeavours underscore the potential of forest-based materials in various applications, ranging from sustainable optoelectronics to bio-based polymers and wood-derived products, contributing to the advancement of eco-friendly and economically viable solutions.

WWSC 2.0 Program 3: Fibers and fiber nanotechnology

Active PIs

KTH: Prof Lars Wågberg – Program 3 responsible, Adj Prof Tomas Larsson, Assoc Prof Torbjörn Pettersson, Prof Daniel Söderberg, Prof Michael Malkoch, Prof Fredrik Lundell, Dr Tobias Benselfelt, Assoc Prof Max Hamedi, Dr Tomas Rosén,
Chalmers: Assoc Prof Merima Hasani, Prof Gunnar Westman, Prof Aleksandar Matic
LiU: Prof Igor Zozoulenko, Prof Xavier Crispin, Dr Aleksandar Mehandzhiyski
Stockholm University: Prof Aji Mathew, Prof Lennart Bergström, Assist Prof, Mika Sipponen

Overview of the activities within the program

The focus areas in Program 3 have been the liberation and chemical modification of the fibrils in the fiber wall of cellulose-rich fibers and the development of filaments and fibril-based materials with a controlled structural organization of the fibrils in the fibers and continuous filaments. The comprehensive research efforts detailed in this report summarizes a multifaceted exploration into the diverse applications of nanocellulose based materials.

WWSC researchers have spent a lot of efforts studying the dynamics of nanocellulose structures in fibers under extreme conditions, particularly through dynamic compression studies. By elucidating the intricacies of pressure effects on cellulose fibers, it has been possible to obtain significant insights into the structural evolution of these materials under extreme conditions. Such findings deepen our fundamental understanding of material behavior and hold substantial promise for applications necessitating resilience, durability and property developments.

In parallel, efforts have been dedicated to identify the fundamental interactions of irreversible interactions between cellulose fibrils, with a specific focus on hornification in cellulose-rich materials. Through careful experimentation and analysis, using a range of high-resolution measuring techniques it has been possible to quantify the kinetics of hornification and identification of possible molecular mechanisms behind the phenomena. This line of investigations not only elucidates fundamental processes but also opens avenues for the development of novel materials with tailored properties.

Moreover, the synthesis of hybrid materials from cellulose nanofibrils and precision dendrimers has emerged as a new development in materials science. These hybrid materials, characterized by their antibacterial properties and biocompatibility, hold promise for applications in biomedicine and environmental remediation. By harnessing the synergistic properties of cellulose and dendrimers, it has been possible to tailor the cellulose based filaments both from a mechanical in biological interaction point of view.

Additionally, the polymerization of functional polymers and hydrogels within the cellulose fiber wall has led to the development of fiber-reinforced hydrogels with exceptional mechanical properties. This innovation expands the repertoire of sustainable materials and offers solutions for applications requiring robustness and flexibility.

Furthermore, research efforts have focused on clarifying the dissolution and coagulation behavior of cellulose in aqueous alkaline systems, paving the way for the development of novel solvents and cellulose-based materials. The development of these new chemistries and processes holds great potential for applications both for the preparation of new advanced materials and for the development of new environmentally friendly processes for cellulose dissolution and regeneration.

Moreover, molecular modeling studies have provided unprecedented insights into the behavior of wood-based materials at the molecular level. By using and developing new computational tools, it has been possible to attain a deeper understanding of structural, electronic, and photonic properties, enabling the design of materials with enhanced performance and functionality.

In conclusion, the combined efforts of the research in the field of nanocellulose and fibers composed of assemblies of nanocellulose underscore the vast potential of these materials to meet pressing societal needs and drive innovation across different application areas where biobased solutions are urgently needed for our future society.

WWSC 2.0 Program 4: Composites for energy and electronics

Active PIs

LiU: Prof Magnus Jonsson, Assoc Prof Dan Zhao
Chalmers: Prof Christian Müller, Prof Per Lundgren, Prof Hans Theliander, Prof Johan Liu

Overview of the activities within the program

Combining forest-based fibers and bulk systems with functional compounds enable a wide range of energy, electronic, photonic and electrical applications. In Program 4, we try to explore and advance along this pathway by introducing p-type conducting polymers, n-type conducting polymers, carbon(ized) materials, silicon dioxide microparticles and metallic materials in order to obtain various active properties on the material level. In addition, we explore a wide range of engineering techniques and production protocols to manufacture fibers, scaffolds and substrates then targeting a specific device or system needed for dedicated applications. Activity in program 4 was largely replaced by new projects in WWSC 3.0, but the results of the few active projects left in program 4 in 2023 are summarized below.

The project on conducting cellulose fibres and yarns for circular electronic textiles, where the recent focus was on developing n-type (electron-conducting) yarns by spray-coating cellulose yarns with a conducting polymer ink was completed and the student defended her PhD thesis Feb 1, 2024.

Conducting carbon fibres derived from hardwood kraft lignin and cellulose were developed and it was demonstrated that the conductivity could be finetuned by varying the lignin-to-cellulose composition ratio, with higher lignin content correlating with higher conductivity.

Mechanically robust nanocomposites providing mixed ionic-electronic conduction were developed using carboxymethylated cellulose nanofibrils (CNF) as the reinforcing agent for the soft polythiophenes with tetraethylene glycol side chains providing the charge transport capabilities. Dry nanocomposites feature a Young’s modulus of more than 400 MPa, and presence of CNF results in a slight decrease in electronic mobility but enhances the ionic mobility and volumetric capacitance. The nanocomposite material successfully was used in an organic electrochemical transistor and show promise as mechanically adaptive mixed ionic-electronic conductors for wearable electronics and bioelectronics.

Cellulose-based metamaterials for passive radiative cooling were used to demonstrate the ability to regulate the temperature of a device at ambient conditions by electrochemically tuning the infrared reflectance and hence the thermal emissivity of the surface.

WWSC 2.0 Program 5: Biocomposites and wood materials

Active PIs

KTH: Prof Lars Berglund – Program 5 responsible, Prof Qi Zhou, Prof Mikael Hedenqvist, Assoc Prof Richard Olsson
Chalmers: Prof Roland Kadar, Assoc Prof Tiina Nypelö
LiU: Senior Assoc Prof Isak Engquist, Assoc Prof Eleni Stavrinidou,

Overview of activities within the program

This program was focused on complex composites. The mechanical function of cellulosics was extended and combined with new functions by added components. The most important research problem was to obtain nanostructural control so that structure and property combinations can be tailored. The major cellulosic substrates are wood by itself or nanocellulose in the form of cellulose nanofibrils (CNF) or cellulose nanocrystals (CNC). The program covered three areas:

5.1 Functional biocomposites and wood materials
5.2 Melt-processing and rheology
5.3 Biocomposites and nanocellulosics

Nanocellulose has dominated the international lignocellulose research field for a long time. The exploration of nanocellulosic aspects of pulp fibers and wood substrates is a new direction evolving from this sub-program. By using pulp fibers and wood veneer substrates, it becomes possible to exploit the favorable nanocellulose organization in the wood cell wall as well as the hierarchical structure of wood (tubular cells for liquid transport combined with oriented cellulose in the cell wall). Sustainable development issues are important in Program 5, including tailored structures for energy harvesting, interesting chemistry with specific functionalities and scientific research related to applications.

The Functional biocomposites part (5.1) includes electronic plants (Stavrinidou, LiU) and other aspects of organic electronics. Zhou, KTH and Engquist, LiU carried out close collaboration with coordinated PhD-thesis projects. The materials problem is to combine electrical and ionic conductivity in functionalized wood substrates. Device-related applications include electrodes and transistors. The ion conductivity of wood itself is improved by sulfonation of the pre-existing cell wall lignin.

In 5.2, Melt processing and rheology, Kadar at Chalmers has started major harvesting of results from earlier methodology developments. These activities were extended by additional KAW-funding for biocomposites collaboration between Chalmers, LTU and KTH. Wood fibers are the main reinforcement component and substantial progress has been reported in terms of rheological understanding (Chalmers).

In 5.3, Biocomposites and nanocellulosics are investigated. Nypelö and coworkers at Chalmers investigated LPMO oxidation, where their substrates were cellulose nanocrystals. Hedenqvist, KTH is interested in barrier properties controlled by gas solubility in the barrier film and the kinetics of the diffusion process. His coatings are inspired by plant cuticles. Olsson, KTH worked on battery recycling problems using cellulose.

List of projects reported in Program 5

5.1 Functional biocomposites and wood materials

5.1.2 Wood template electronics I Engquist, LiU

5.1.3 Distributed electronic functions in wood, from soil to xylem E Stavrinidou, LiU

5.1.4 Functionalized wood templates Q Zhou, KTH

5.2 Melt-processing and rheology

5.2.2 Advanced Rheological Characterization R Kadar, Chalmers

5.3 Biocomposites and nanocellulosics

5.3.2 Mimicking natural cuticle barrier materials M Hedenqvist, KTH

5.3.3 Inorganic-organic nanocellulose hybrids R Olsson, KTH

5.3.5 Assembly of hierarchical materials from biopolymers and particles T Nypelö, Chalmers

WWSC 3.0 Program I: Materials biorefinery

Active PIs

Chalmers: Assoc Prof Merima Hasani – Program I responsible, Assoc Prof Johan Larsbrink – Program I co-responsible, Prof Lisbeth Olsson, Prof Gunnar Henriksson
KTH: Prof Martin Lawoko, Assoc Prof Lauren McKee, Prof Francisco Vilaplana, Assoc Prof Olena Sevastyanova
LiU: Prof Reverant Crispin

Overview of the activities within the program

The work in Program 1 aims at providing structural and processing knowledge required to enable highly selective and material efficient decoupling of the forest biomass with structure and functionality control. Our approach relies on gaining a deep mechanistic understanding of the decoupling processes whether pertaining to the processability behavior of the biomass components or their structural conversions associated with applications.

With resource efficiency in biomass utilization as a priority, a particular focus is placed on recovery and upgrading of underutilized and waste resources, ranging from hemicelluloses and bark to sludge generated in pulp mills.

The work on bark valorization relies on identifying microbial pathways for its deconstruction and modification of individual components. In their previous work Larsbrink *at al*. have identified removal of resin acids as one of the main steps during microbial bark degradation and isolated a new bacterial species identified as the main resin acid degraders. Continued work is now focused on understanding degradation pathways of resin acids and utilizing this knowledge for their functionalization. At the same time Olsson *at el.* work on identifying and characterizing esterases (cutinases/suberinase) that can be used to release long chain fatty acids (LCFA) from suberin in bark, the focus being on developing methodology to quantify the LCFAs and increase secretion of these enzymes from the two recently identified fungal species (*Talaromyces* sp2. AS616-3 and *Talaromyces* sp4. ASM115). Additionally, the group explores LPMO enzymes supplementary to cellulytic enzymatic cocktails and their activity on mildly steam-pretreated spruce. Enzyme discovery is also employed in the work aiming at valorisation of sludge streams generated during paper pulp production (McKee *at al*.). Microbes grown on sludge collected from a paper pulp mill are studied to uncover new species and consequently new enzymes capable of metabolizing the organic sludge material while being resistant to rather harsh conditions associated with sludge streams.

Another focus area of the program is developing the decoupling approaches for improved selectivity and functionality control of the obtained (decoupled) building blocks for targeted applications. In this respect, a glycerol-based delignification investigated by Henriksson *et al*. can potentially provide access to as well cellulose pulp as a new type of lignin separated under atmospheric conditions, along with the possibility of co-producing hydrogen gas from the spent delignification liquor. The initial studies have been dealing with the challenges of impregnating wood with glycerol and understanding the basics of delignification kinetics. With the prospect of obtaining aldehyde functionalized polysaccharides, oxidative extraction of hemicelluloses is employed in the work of Hasani *et al.* The efforts aim at promoting solubility and mass transport of hemicelluloses in the wood tissue by a partial oxidative opening of their pyranose rings, expected to enhance flexibility and mobility of the backbone, while decorating them with aldehyde functionalities. The initial research has been focused on developing analytic methodology to assess the oxidative effects on as well extracted polymers as the solid wood residue. Vilaplana *et al*., on the other hand, use oxidizing enzymes to selectively introduce reactive oxidized groups on the hemicellulose covering the cellulose fibers as a means of enabling further functionalization of these surfaces. Current focus is on preparation of hemicellulose and holocellulose substrates as a reference for the upcoming enzymatic laccase delignification. Precision – in lignin separation – is also the ultimate goal in the work of Lawoko *et al.* who work on gaining fundamental understanding on lignin polymerization, linkage sequences and interactions in the cell wall as a pre-requisite for its controlled extraction. The emphasis is on mimicking lignin polymerization in order to elucidate interactions affecting formation of lignin structure and its interplay with the other cell wall components. The group works in parallel on developing analytics that would enable precise determination of molecular weight and linkage sequences of the isolated lignin by combining chromatography, spectroscopy and spectrometry methods. Of particular interest is use of X-ray scattering (SAXS/WAXS) for real time monitoring of lignin polymerization and establishment of its interactions on different size levels.

Further valorisation of lignin revolves around formation of lignin nanoparticles (LNPs), as promising well-defined nano-building blocks for broad material applications. Sevastyanova *et al*. explore how functionalization of lignin with fatty acids (of varying lengths) affects its self-assembly into LNPs. Preliminary results point out a critical impact of chemical functionalization on their structure and potential applications. Chemical functionalization of lignin nanostructures is also the main approach of Crispin *et al.* aiming at improving their charge storage capacity. Introduction of nitro and azo groups has been explored in the initial efforts expanding also to investigations of suitable model compounds such as dinitrobenzene showing an increased charge storage activity.

WWSC 3.0 Program II: Wood components and interfaces

Active PIs

KTH: Prof Eva Malmström – Program II responsible, Prof Lars Wågberg – Program II co-responsible, Prof Monica Ek, Dr Linda Fogelström, Prof István Furó, Prof Minna Hakkarainen, Prof Mats Johansson, Prof Martin Lawoko, Prof Michael Malkoch, Prof Karin Odelius, Assoc Prof Torbjörn Pettersson, Assoc Prof Per-Olof Syrén, Prof Francisco Vilaplana, Assoc Prof Mika Sipponen (SU).
Chalmers: Prof Lars Evenäs, Assoc Prof Giada Lo Re, Prof Gunnar Westman.
LiU: Dr Viktor Gueskine, Assoc Prof Renee Kroon, Assoc Prof Mikhail Vagin.

Overview of the activities within the program

Program II aims at acquiring deeper knowledge regarding lignin, hemicellulose, small molecules and modifications thereof to pave the way for wood-based bioplastics, coatings, adhesives, and property-enhancing additives as well as tailored polymers for interfacial engineering. Further, biomimetic and synthetic approaches for engineering of surface properties will be investigated since interfacial adhesion between components is of utmost importance, both to accomplish durable, as well as recyclable/reusable materials. An overarching goal is to develop materials or material additives that can support a decreased dependence of fossil-based materials, and hence to accelerate the transition into circular materials. The program has been under a start-up phase during 2023 and a plethora of activites have been initiated.

Alternative pathways to increase the charge density on pulp fibers to increase availability have been explored. It was found that when itaconic acid was used for modification, the increase in charge density of the pulp fibers was almost ten-fold.

The effect of lignin structure has previously been demonstrated to be important for material properties. It has been further investigated how variations in lignin structure affect interactions at different length scales, from molecular to macro-levels, regarding solution behavior and solid interfaces. Initial studies have involved the creation of functionalized "native-like" lignin, obtained through mild extraction to yield a more open lignin structure with remaining β-O4 linkages compared to technical Kraft lignin.

Another area of focus of Program II involves grafting hydrophobic oligomers onto carbohydrate substrates through oxime-based linkages, offering stability in water and reversibility under specific chemical stimuli. Forest- and other biomass-based materials have been utilized to synthesize conjugated monomers and polymers, aiming at creating high-performance opto-electronic materials. Specifically, the design of monomers such as furan, pyrrole, and thiophene, as well as more complex multifused conjugated monomers, has attracted interest to serve as building blocks for functional materials. Robust and electroactive hybrid materials, by combining cellulose derivatives and functionalized conjugated polymers, have been accomplished. This involves the design and synthesis of conjugated polymers to improve interactions with cellulosic materials, focusing on properties like electrical and mechanical performance, long-term stability, water-based processing, and reversible crosslinking chemistry. Sustainable aqueous flow batteries (FB) using stable organic compounds as active materials and cellulose-based membranes have been investigated. The initial stages involve optimization of basic procedures and parameters, considering factors such as electrodes and membranes' performance.

Lastly, ongoing research investigates how the degradation of PLA/lignin blends is influenced by different types of lignin, with clear differences observed in PLA degradation rates depending on the lignin component. This project involves characterizing materials before and after aging to understand structural changes in lignin and the influence of different lignin types on PLA degradation.

In summary, Program II encompasses diverse research areas aiming to develop sustainable materials suitable for various material applications.

WWSC 3.0 Program III: Processing and structural materials

Active PIs

KTH: Prof Daniel Söderberg, Program III responsible, Assoc Prof Jakob Wohlert, Assist Prof Yuanyuan Li, Prof Kristiina Oksman (LTU).
Chalmers: Prof Anette Larsson, Prof Roland Kádár
LiU: Prof Feng Gao, Prof Igor Zozoulenko

Overview of the activities within the program

Within the project, *Wood-based Substrates for Organic Photovoltaics*, a PhD student has been trained in fabricating and analysing solar cells prepared on glass substrates to flexible PET-based substrates. The project investigates using wood-based transparent substrates for organic photovoltaics (OPVs), focusing on bacterial cellulose and TEMPO-oxidized cellulose nanofibers (TEMPO-CNFs). The investigation addressed the solvent resistivity, surface roughness, and transparency of these substrates. Various techniques to replace indium tin oxide (ITO) with eco-friendly and low-cost alternatives were explored, such as evaporated silver, silver nanowires, and silver paint on glass and PET substrates. Further training in inkjet printing with silver nanoparticle ink was conducted in collaboration with the printed electronics arena (PEA).

As a key to fabricating energy-efficient lignocellulosic materials, there is a need to develop drying processes. Within the project, *New Routes for Water Removal During Processing of Lignocellulosic Material Concepts*, a PhD student has been recruited to develop our knowledge of mechanisms for modifying water interactions with lignocellulosic materials to find more energy-efficient ways to remove water. This involves examining external forces like electrochemical, acoustic, or electromagnetic fields. Initial activities focused on developing model material concepts and evaluating characterisation methods, including using the ForMAX beamline at MAX IV and suitable instruments for Quasi-Elastic Neutron Scattering (QENS), where several proposals for instrument time have been submitted.

In the project *Mass Transport of Wood Components in Processed Wood* the effect of shorter exposure times of ionic liquids to wood components is studies in pursuit for the extraction of well-defined biopolymers and larger extraction yields. Various pre-treatment methods, such as ultrasound, are employed to open the fibre walls and increase mass transport, allowing shorter exposure times. A temperate flow-through reactor is used to study the extraction process, and the collected liquids are analysed for properties like viscosity, osmolality, chemical content, structures, and molecular weight of the wood components. Further structural analysis uses X-ray scattering, spectroscopic methods, titration, and imaging techniques, including Raman microscopy, X-ray fluorescence, Nano-SIMS, and SEM, with MRI to monitor concentration profiles in real time.

This project is collaborating with the project *Modelling Drying Effects in Cellulose Materials*, which has recruited a PhD student who studies drying effects through a combination of atomistic computer simulations and experimental characterisation. The study examined capillary forces and their influence on cellulose substrates during drying, exploring how chemical surface modifications impact the interaction between cellulose fibrils. The project investigated the significance of water trapped at the interfaces and the thermodynamics of cellulose nanofibril aggregation under various conditions.

Another modelling project is *Computational studies of wood-based materials and devices*, which has focused on simulating and modelling cellulose-based materials' morphological and transport properties. Studies included simulations of cellulose-based polymer gel electrolytes for lithium-ion batteries, membranes, and conducting polymers. The work involves all-atom and coarse-grained molecular dynamics simulations to study cellulose regeneration.

Another project that uses advanced characterisation techniques, including the ForMAX beamline, is *Hyphenated Rheology for Multiscale Flow Assembly of Nanocellulose Systems for Additive Manufacturing*. Activities have involved designing a novel optical system and complementary work. The project aimed to achieve a comprehensive hierarchical characterisation of nanocellulose-based systems through bulk rheology, Rheo-SAXS, and Rheo-PLSM (polarised laser scanning microscopy). These techniques were used to study the rheological properties of nanocellulose for additive manufacturing and coating applications, focusing on cellulose nanocrystals and blends with cellulose nanofibrils. The work also explores the role of surface modifications in facilitating directed flow assembly.

Also, the project Structure-Property Relations of Cellulose Fibre Composites aims at utilising X-ray tomography at ForMAX and on a laboratory scale, in combination with time-resolved image-based methods for non-intrusive measurements of deformation and moisture transport. It is focused on understanding the internal structure and properties of cellulose filaments and their behaviour in composite structures. A multiscale computational model based on the Discrete Element Method (DEM) will be employed to predict properties like elasticity, plasticity, and fatigue cracking. Structural information was gathered using X-ray tomographic images, with time-resolved image-based methods applied for non-intrusive measurement of deformation and moisture transport.

Finally, the project *Wood Substrate Nanostructure Control Towards Sustainable Hydrovoltaic Power Generation* focuses on developing a scalable and sustainable wood-based power generator for hydrovoltaic power generation. Activities include fabricating and characterising wood aerogels with high specific surface area and enhanced surface charge for hydrovoltaic energy harvesting. This includes exploring the influence of various wood treatments, such as delignification and carbonisation, on hydrovoltaic power generation.

Overall, the programme covers a broad range of activities centred around the innovative processing and characterisation of wood-based materials and techniques for sustainable energy solutions, additive manufacturing, and composite structures.

WWSC 3.0 Program IV: Functional materials

Active PIs

LiU: Prof Mats Fahlman – Program 4 responsible, Prof Isak Engquist – Program 4 co-responsible, Dr Mary Donahue, Prof Simone Fabiano, Prof Magnus Jonsson, Assoc Prof Renee Kroon, Prof Eleni Stavrinidou, Prof Klas Tybrandt
KTH: Prof Monica Ek, Prof Mikael Hedenqvist, Prof Lars Wågberg, Prof Qi Zhou, Assist Prof Mika Sipponen (SU)
Chalmers: Prof Aleksandar Matic, Prof Christian Müller, Prof Gunnar Westman

Overview of the activities within the program

Forest biopolymers provide an array of appealing characteristics for the areas of (bio)electronics, energy technology, and photonics. These features involve structure, hierarchy, and organization of materials ranging from the atomic, macromolecular, all the way to the macroscopic scales. In addition, the forest-materials also provide some key-assets, related to chemical, electrochemical, and physical properties, being of particular interest for advanced sustainable technologies. In program IV we explore and develop material amalgamations based on functional organic and inorganic materials and the different forest biopolymers.

Functional materials for interfacing with living tissue, human or plant, are important parts of program IV. In a joint LiU-KTH effort, cellulose-based electrode coatings of composite materials that have electronic and ionic conductivity are being developed. The aim is to achieve mixed conduction in the same material and also ion- or electron-only materials. The materials also shall provide adhesive properties and be available as gels and/or foams to ensure stable contact with the biological tissue for non-invasive therapeutic stimulation applications. Bioelectronic growth scaffold for plants, eSoil, is the subject of another project, where a cellulose-based mixed ion-electron conductor is used to provide electrical stimulation to the plants' root system and growth environment in hydroponics settings. Here, accelerated growth of barley seedlings has been demonstrated and research is ongoing to uncover a more complete understanding of the mechanisms involved.

Several projects within program IV is focused on sustainable battery technologies, developing functional materials suitable for a variety of purposes. A joint KTH-LiU effort developed a facile strategy for efficient impregnation and in-situ polymerization of conducive polymers enabling the fabrication of conductive wood (electrodes). In addition, they fabricated a wood foam with a unique porous cell wall structure with arrays of parallel sub-100 nm pores channels in the secondary cell wall. This wood foam has great potential as a hierarchically porous and flexible template for a wide range of applications also outside of battery technologies at it enables incorporation of large particles and functional polymers of high molecular mass.

A project at Chalmers explores the possibility to tailor biopolymers to improve stability of metal anodes in Zn-batteries. Here design and development of separator materials based on cellulose nanocrystals are aided by advanced characterizations using synchrotron radiation and tests in Zn|Zn-battery cells.

Design and development of biocomposites for stretchable and biodegradable rechargeable batteries is the topic of an LiU project. Materials developed for the various constituent part of the technology includes stretchable hydrogels based on cellulose nanofibrils and gelatine, metal-free kirigami current collectors based on cellulose-nanographite composites as well as dispersions of lignin, PEDOT and PACA to serve as conductive flowing electrodes in fluid-based batteries.

A joint LiU-Chalmers project pursues the synthesis of functionalized conjugated polymers for suitable for use in advanced forest-based materials with the aim of creating recyclable electroactive cellulose coatings. A developed polymer allows for a reversible crosslinking via acid-base chemistry and the hydrogen bonding that it imparts reinforces the electroactive polymer film itself and offers improved interaction with cellulose substrates through hydrogen bonding. The same functionalized polymer was also demonstrated to enable water-based processing of a stable n-type polymer when used as an additive, of great utility to conducting ink formulation.

Other functional wood-based materials developed in program 4 include efforts at KTH developing barrier materials by mimicking the cuticle (suberin and/or cutin) structure for applications on wood-based materials, activities at SU on developing spherical lignin nanoparticles with useful intrinsic properties such as redox activity and UV light absorbance, and sustainable energy-regulating photonic cellulose - conducting polymer composites explored at LiU.

WWSC Academy

Persons involved

Prof Anette Larsson, Chalmers, Assoc Prof Lauren McKee, KTH, Prof Igor Zozoulenko, LiU

Objectives

The WWSC Academy is a cornerstone of WWSC and plays a critical role in fostering a new cohort of scientists ready to lead the work towards a circular bioeconomy based on forest resources. Its primary mission is to

- provide WWSC PhD students with graduate courses that focus on fundamental understanding of fractionation and isolation of wood components, wood biopolymers, fibers, fibrillation into nanocellulose, and assembly of components into wood-based materials. With more than 30 graduated in 2014/15, 32 graduated in 2018, 42 in 2023, and with an enrolment of more than 35 students since January 2023, the WWSC Academy facilitates and improves the participants' scientific development and acts as an important complement to the comprehensive postgraduate education provided by the partner universities.
- provide WWSC PhD students with two courses per year, in total seven courses, which are mandatory for all WWSC PhD students to attend

In addition, all PhD students have to present their research as pitch- and poster presentations during the WWSC Workshops. The best presentations receive awards.

Activities

During 2023, WWSC Academy graduated 42 students in June 2023. The WWSC Academy also organized the first course for the new batch of students: Introduction to WWSC and WWSC Academy in October 2023 at Skytteholm, located at Ekerö just outside Stockholm. The course contained presentations by the program responsible for each WWSC Program and an opportunity for the students to meet in each program. In addition, the students also got a taste of simulations and modelling, advanced characterizations, sustainable development and the principles of green chemistry, entrepreneurship and how to write an abstract, make a poster, and pitch your research. The examination was the preparation of a poster and pitch, which they later presented at the WWSC biannual workshops. In total, 36 PhD students participated; 33 from WWSC and 3 from Treesearch. The PhD students came from; KTH (12), Chalmers (7), LiU (12), SU (3), LTU (1), MIUN (1).

Figure: The graduation of the third batch of WWSC Academy students was held at Sånga-Säby, Ekerö, in June 2023.

Figure: The first course for the fourth batch of WWSC Academy students, Introduction to WWSC and WWSC Academy, was held in October 2023 at Skytteholm. In the photos above:
The WWSC Director Eva Malmström presents WWSC; Magnus Wikström, MaWi Development and Johan Gising, AB Karl Hedin, have just discussed entrepreneurship with the students; students test wood-based materials; students in the lecture hall; a group photo of all the students participating in the course.

Graduated WWSC PhD students during 2023

Sozan Darabi	Chalmers	Electrically Conducting Cellulose Yarns for Electronic Textiles
Monika Tõlgo	Chalmers	Discovery and applications of family AA9 lytic polysaccharide monooxygenases
Alexandros Alexakis	KTH	Nanolatexes: a versatile toolbox for cellulose modification
Qilun Zhang	LiU	Materials and interfaces for sustainable organic solar cells
Tijana Todorovic	KTH	Polysaccharide-based wood adhesives
Maria Karlsson	KTH	Protected Lignin Biorefining: Fundamental Insights on Lignin Reactivity
Linnea Cederholm	KTH	Bio-based thermoplastic elastomers
Vasileios Oikinomou	LiU	Cellulose-based Conducting 3D and 2D Composites for Applications in Plant Science and Responsive Systems
Billy Hoogendoorn	KTH	Inorganic-organic nanocellulose hybrids
Ioanna Sapouna	KTH	Biosynthesis, interactions, and structure of native lignin
Iuliana Ribca	KTH	Lignin derivatives for polymers
Saül Llàcer Navarro	Chalmers	Assembly of hierarchical materials from biopolymers and particles
Faridah Namata	KTH	New specific chemical modifications for fibre functionalization including topo-selective modifications and advanced structure and chemical characterization
Sylwia Wojno	Chalmers	Advanced rheological characterization
Gabriella Mastantuoni	KTH	Functionalized wood templates
Natalia Fijol	SU	Hierarchically porous biobased 3D filters for water purification
Shirin Naserifar	Chalmers	Functionalizes cellulose structures from aqueous alkaline systems
Roujin Ghaffari	Chalmers	Mass Transport in Wood Disintegration: Implications for the Pulp and Paper Industry
Divyaratan Kumar	LiU	Water-in-polymer salt electrolyte (WiPSE) for sustainable lignin batteries
Silan Zhang	LiU	Organic Electrochemical Transistors: Materials and Challenges
Van Chinh Tran	LiU	Wood Templated Organic Electronics

WWSC
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WWSC Summer Workshop 2023

Sånga-Säby, Ekerö
June 19-21, 2023

Monday June 19

Buses from Stockholm C and Norrköping Resecentrum to Sånga-Säby

12.30	*Lunch*
13:30	**Welcome address:** Eva Malmström, WWSC Director **Presentation of WWSC 3.0 Programs:** Merima Hasani, Chalmers, Eva Malmström, KTH, Daniel Söderberg, KTH, Mats Fahlman, LiU
14:30	**Innovative Biomaterials from Trees:** Paul Gatenholm, Chalmers
15:15	*Break (possibility to check in to hotel room)*
16:15	**WWSC Academy Graduation ceremony**
17:15	**Poster session**
19:00	*Dinner*

Tuesday June 20

09:00	**Processing Cellulose Composites Using Cellulose-Based Emulsions:** Stephen Eichhorn, University of Bristol, UK
09:45	**Electronics and electrochemical energy technology made from forest-based materials:** Magnus Berggren, LiU
10:30	*Break*
11:00	**Sustainability workshop:** Fredrik Lundell, KTH
13:00	*Lunch*
14.00	**Biotechnology for biomaterials:** Lauren McKee, KTH
14:30	**Evaluation of the recombinant cutinase from Fusarium Solani and Cryptococcus to extract fatty acids from suberin:** Wissal Ben Ali, Chalmers
14:45	**SEM combined with FIB cross-sections revealing the impact of steam explosion pre-treatment on the Norway spruce wood microstructure:** Matteo Maria Brollo, Chalmers
15.00	**Conjugated polymers – functionalization for cellulose-based hybrid materials:** Renee Kroon, LiU
15:30	*Break*
16:00	**Synthesis of Biobased Chemically Recyclable and Enzymatically Degradable Schiff base Polyesters for Circularity:** Sathiyaraj Subramaniyan, KTH
16.15	**Biogenic carbon flows – Status and possibilities:** Stefan Svensson, RISE
17.00	*Activity*
19:15	*Dinner*

Wednesday June 21

09:00	**Nanofibrillar foams: from single fibrils to phonon scattering to upcycling of textile waste:** Lennart Bergström, Stockholm University
09:45	*Break (WWSC LG meeting and latest check-out from hotel room)*
10:50	**From wood towards textile waste as raw materials for fabricating porous cellulose-based materials for thermal insulation and water purification:** Varvara Apostolopoulou Kalkavoura, Stockholm University; **Exploring structure-property relationships in lignin-based thermosets:** Iuliana Ribca, KTH; **Polysaccharide-based wood adhesives:** Tijana Todorovic, KTH; **Biorefining for well-defined lignin with tunable properties:** Maria Karlsson, KTH; **Exploring the use of cellulose as a precipitation agent of metal ions for metal recycling:** Billy Hoogendoorn, KTH
11:50	**Anisotropic nanofibrillar hydrogels: fundamentals and electro-mechanical applications?:** Tobias Benselfelt, KTH
12:20	**Concluding remarks**
12:30	*Lunch*
13:45	*Buses leaving Sånga-Säby for Stockholm C and Norrköping Resecentrum*

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WWSC Winter Workshop 2023

Bohusgården, Uddevalla
November 21-23, 2023

Tuesday November 21

Buses from Skövde C and Gothenburg C to Bohusgården

12.30	*Lunch*
13:30	**Welcome address:** Eva Malmström, WWSC Director **WWSC Programs:** PI: Merima Hasani, Chalmers; PII: Eva Malmström, KTH; PIII: Daniel Söderberg, KTH; PIV: Mats Fahlman, LiU
14:30	**Drug-eluting polyelectrolyte microgels: Microstructure and release mechanism:** Per Hansson, Uppsala University
15:15	*Break*
15:45	**WWSC Academy Pitch session**
16:45	*Short break*
17:00	**Poster session 1 & 2**
19:00	*Dinner*

Wednesday November 22

09:00	**Allocated time for research project meetings and WWSC LG meeting**
10:00	**Biomaterials for the next generation of regenerative & restorative bioelectronic systems:** Maria Asplund, Chalmers
10:45	*Break*
11:15	**Nanocellulose-protein interactions, self-assembly and hybrid materials:** Gustav Nyström, Empa
12:00	*Lunch*
13.00	**Wood-based biorefining: Why – Past – Present – Challenges:** Hans Theliander, Chalmers
13:45	**Presentation of incoming Assistant Professors in WWSC:** Alexander Groetsch, KTH, Alexander Holm, LiU, Liyang Liu, Chalmers
14:45	**WWSC Program meetings (Program I – IV)** *including coffee break*
16:30	**Activity**
19:00	*Dinner*

Thursday November 23

09:00	**Adhesion and fracture of soft dissipative materials:** Matteo Ciccotti, ESPCI Paris PSL
09:45	**Introducing thermoplasticity to hemicelluloses:** Anna Ström, Chalmers
10:30	*Break*
11:00	**Finding challenges and solutions through collaboration – modifying and analyzing cellulose and xylans:** Tiina Nypelö, Aalto University
11:45	**Concluding remarks**
12:00	*Lunch*
13:30	*Buses leaving Bohusgården for Gothenburg C and Skövde C*

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WWSC Bibliometry

Aim: To follow the impact of the research conducted in WWSC in the scientific community and determine the development. The bibliometric data can serve as a comparison basis with other groups, centers, and universities.

The basis for this bibliometric report is the curated list of publications from Chalmers, KTH and LiU for 2019-2022. Measures used are: the number of publications, the standing of the journals they are published in, and the number of citations.

Number of publications

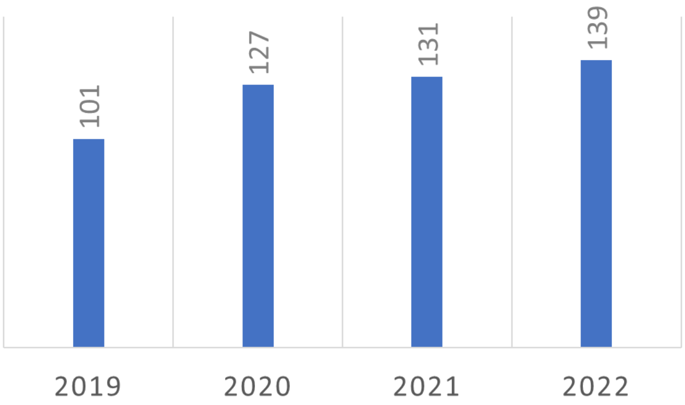

Figure: Number of publications from WWSC per year 2019-2022.

During 2019-2022, WWSC published 498 publications in total, which is 50 % higher than the corresponding number for the 2014-2018 time period.

FWCI – Field-Weighted Citation Impact

FWCI measures how well-cited the publications are compared with the subject area as a whole. FWCI > 1.0 means an above average citation rate.

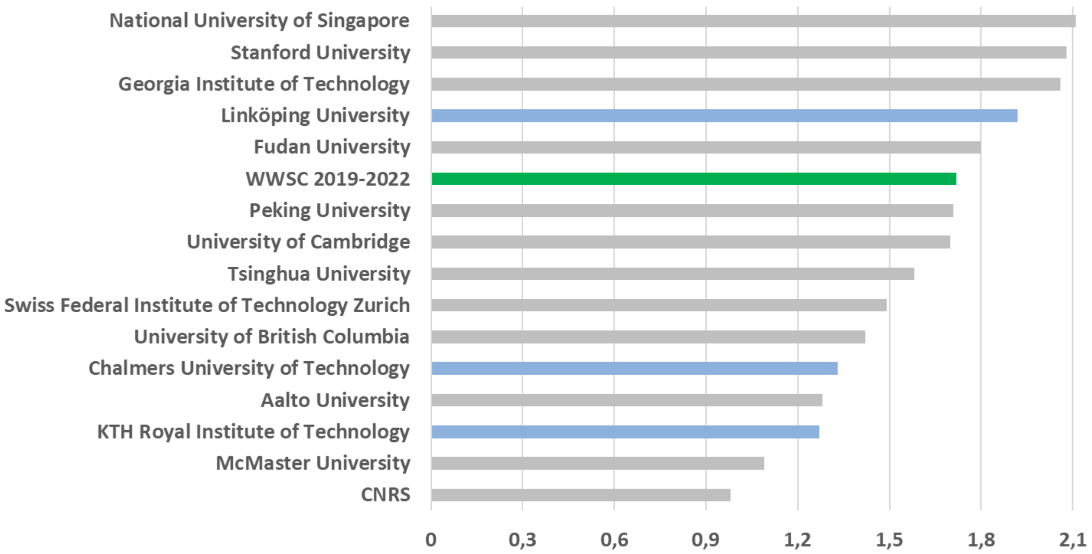

Figure: The world-leading universities in the subject area “materials science” according to FWCI, during 2019-2022.

For 2019-2022 the FWCI of WWSC was 1.72, which places WWSC on place 6 compared with other leading instutions (with a focus on wood science)in the subject area of “materials science”, which is one place higher than for 2014-2018.

SNIP – Source-Normalized Impact per Publication

SNIP measures the citation impact of scientific journals. The indictor corrects for differences in citation practices between fields. SNIP > 1.0 means that the journal's citation rate is above the average.

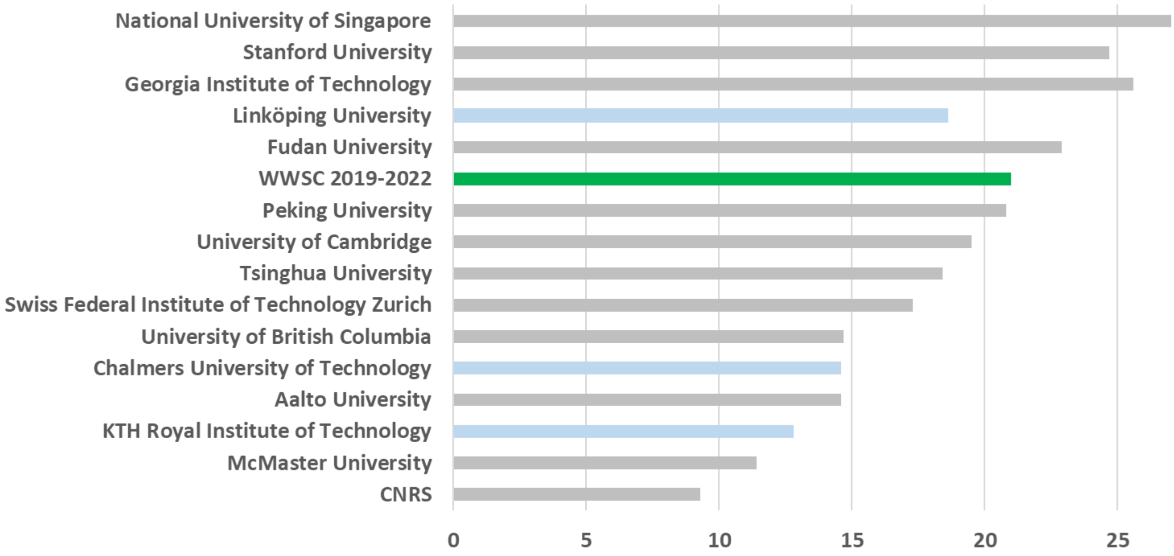

Figure: Output in top 10 % citation percentiles by SNIP for the world-leading universities in the subject area of materials science during 2019-2022.

The figure shows that 21 % of WWSCs publications are published in journals that are in the top 10 % citation percentiles by SNIP. Moreover, 98 % of all WWSC publications are cited.

Journals we prefer to publish in

Scopus Source	Scholarly Output ↓	Citations	Authors	SNIP 2022
Carbohydrate Polymers	21 ▲	227	89 ▲	1.862
ACS Sustainable Chemistry and Engineering	20 ▼	383	85 ▼	1.372
Cellulose	20 ▼	316	81 ▼	1.197
Biomacromolecules	17 ▼	283	78 ▼	1.112
ACS applied materials & interfaces	13 ▼	305	75 ▼	1.429
Green Chemistry	12 ▼	198	54 ▼	1.753
ACS Nano	10	438	52 ▼	2.423
Advanced Materials	10 ▲	471	69 ▲	4.100
Journal of Materials Chemistry A	10 ▲	117	53 ▲	1.637
Advanced Functional Materials	8 ▲	118	80 ▲	2.586

also popular 2014-2018

not in top 10 2014-2018

Figure: Publication data for the top 10 journals with most WWSC publications.

In comparison with 2014-2018, during 2019-2022 WWSC published in more high-impact application-oriented journals and less in wood- and composites science journals such as Holzforschung and Composites Science and Technology.

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WWSC Management team

The WWSC management consists of representatives from the three member universities: KTH Royal Institute of Technology, Chalmers University of Technology and Linköping University.

KTH


Eva Malmström


Daniel Söderberg


Linda Fogelström


Lars Wågberg


Lars Berglund

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Lisbeth Olsson


Merima Hasani


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