Fibre Science and Communication Network
A research centre at Mid Sweden University

FSCN
PART OF MID SWEDEN UNIVERSITY

FSCN Annual Report 2016

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Faculty of Science Technology and Media
Fibre Science and Communication Network
Mid Sweden University
Sundsvall 2017-03-01

FSCN Annual Report 2016

Printed by Mid Sweden University, Sundsvall
ISBN: 978-91-88527-11-0

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Report series 1650-5387

Table of contents

Introduction

FSCN is part of the research environment on Transformative Technologies at Mid Sweden University. Our specialty is research on the manufacturing processes and products of forest-based industries, both the traditional and completely new. Our strongest research area is high-yield pulping and especially its energy efficiency. In a large program that now ends we have demonstrated with full-scale trials how 25% of electricity can be saved in the manufacture of mechanical paper grades (cf. Prof Engstrand). When implemented, our research findings would save the Swedish paper industry ca. 40 M€ per year and reduce CO2 emissions from the electricity production by over 600.000 tons per year. This is equivalent to e.g. 3% of the emissions of all transportation in Sweden.

Green energy systems for transportation and other sectors is another strong research area. We study how the manufacturing processes of large surfaces in paper industry can be used to bring down the cost of electrical vehicles. Graphite is one of the materials needed in the storage devices of electricity (supercapacitors). Last year we succeeded in developing a manufacturing process for nanographite (mixture of graphite and graphene) that is orders of magnitude more effective than other known processes (cf. Nicklas Blomquist). When can now run manufacturing trials of supercapacitors on pilot-scale paper coating machines.

New ways of using cellulose is the third major research area. Here we study among others water-based and environmentally benign dissolution of cellulose. That can be used to change the properties of fibres and paper, or to make completely new materials. For example, we have prepared nanocomposites of cellulose and chitosan (cf. Jiayi Yang) and of cellulose and metallic nanoparticles (cf. Alireza Eivazihollagh) from aqueous solutions. Such materials have interesting combinations of mechanical strength, biocompatibility and thermal stability with electronic, catalytic, magnetic and biomedical properties.

More information and references to these and many other interesting and important results can be found in this Annual Report of FSCN. A special feature of our research is the broad network of companies that are involved in essentially all of our projects, see the listing on the next page. We are grateful for their engagement and support.

Kaarlo Niskanen, Research Director FSCN

Partner companies

The main part of partner companies involved in research projects at FSCN 2016.

A Fredriksson Research and Consulting (AFRC)
Acreo
Aditiya Birla Group
Akzo Nobel
Andritz
Andritz Iggesund Tools
Biogas i Mellannorrland
BeinZero
BillerudKorsnäs
Bioisolator Acustica
Bla Traden
Bucher Emhart Glass
Capisco
Cobolt
Colabitoil
Dametric
Elektronikdesign
Eko Kem
Erigovis
Eurocon
Fiber Optic Valley
Fiber-X
Flint Group
Frontway
Holmen
HL Display
Innventia
Iggesund Paperboard
IMT Materialteknik
Inovocell
IUC Sjuhärad
Kinnarps
Kubikenborgs Aluminium
LAB Service
Laser Nova
LaserCut
Leading Light
Mantex
Metsä Board
MittSverige Vatten och Avfall
Mondi Dynäs
Mora Mast
MoRe Research
Munksjö Paper
NALCO
Nano Nordic
Nordic Barrier Coating
Nordic Paper
Norske Skog
OCE Printing Systems
OrganoClick
Permascand
PulpEye
Permobil
Pöyry
QualTech
Ragn-Sells
Rise Bioeconomy
SCA
SEKAB
Sense Air
Sensient Imaging Technology
Servanet
Sjuhärads Färgeri
Sicomp
Smart Textiles
Sol Voltaics
SP Processum
St. Gobain Abrasives
Stena Recyling
SSG

Staga Sweden
Stora Enso
STT Emtec
Sundsvall Elnät
Sundsvall Energi
Superior Graphite
Swema Industriteknik
Svenska Pappersbruket
Svenskt Konstsilke
Swerea IVF
Sylvestris
Termo Gen
TetraPak
Thyréns
Trikåby
Tärnsjö Garveri
Valmet
Vesta Si Europe
Windforce Airbuzz Holding
Woxna Graphite
Z-Signaler
ÅF- Ångpanneföreningen
Åkroken Science Park

Research funding

EUROPEISKA UNIONEN
Europeiska regionala utvecklingsfonden

Landstinget Västernorrland

VINNOVA

Vetenskapsrådet

Energimyndigheten

formas
Forskningsrådet för miljö, areella näringar och samhällsbyggande, Formas

KK-stiftelsen

Sundsvalls kommun

WoodWisdom-Net

Bo Rydin Stiftelse

Kempestiftelserna

Stiftelsen Åforsk

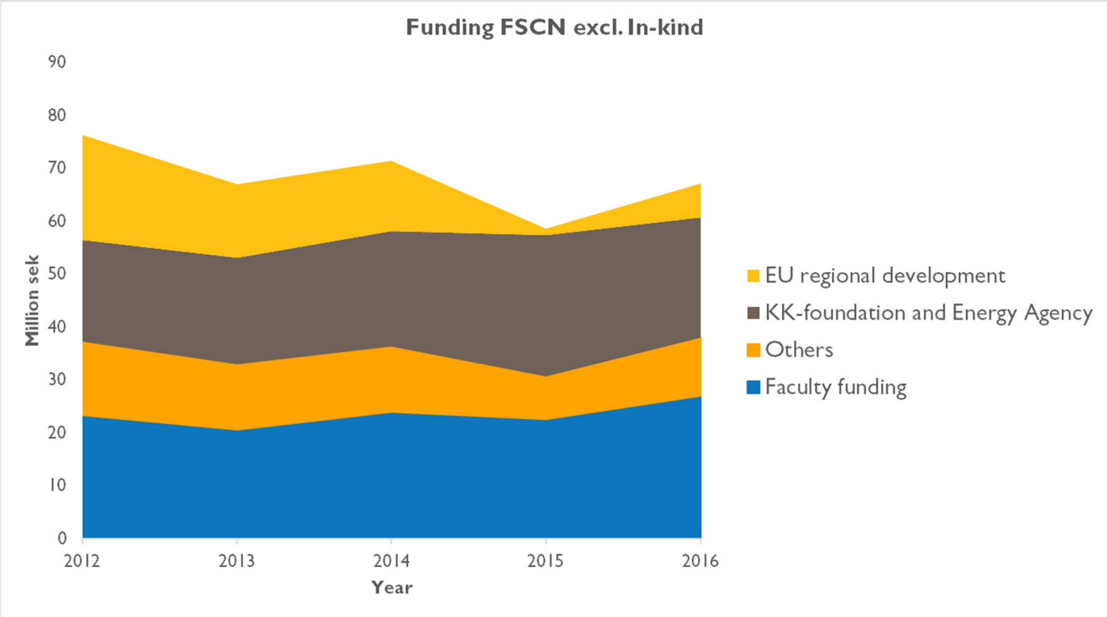
Stiftelsen Nils och Dorthi Troëdssons forskningsfond

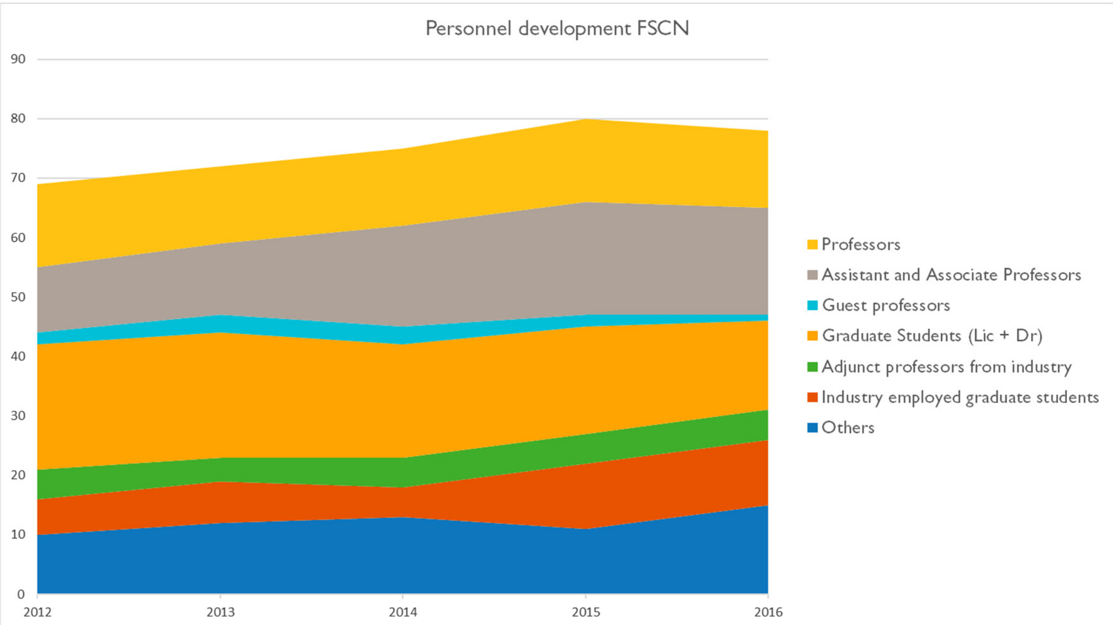
Doctoral and Licentiate Degrees

- Nelsson, Erik; ***Improved energy efficiency in mill scale production of mechanical pulp by increased wood softening and refining intensity***; Doctoral Thesis 242: Mid Sweden University, ISSN 1652-893X; ISBN 978-91-88025-59-3 (2016)
- Henshaw Osong, Sinke; ***Mechanical Pulp-Based Nanocellulose: Processing and applications relating to paper and paperboard, composite films and foams;*** Doctoral Thesis 245: Mid Sweden University, ISSN 1652-893X; ISBN 978-91-88025-64-7 (2016)
- Duan, Ran; ***On Shaping Mechanical Properties of Lignocellulosic Materials by Benign Chemical Processing;*** Licentiate Thesis 124: Mid Sweden University, ISSN 1652-8948; ISBN 978-91-88025-72-2 (2016)
- Blomquist, Nicklas; ***Large-Scale Nanographite Exfoliation for Low-Cost Metal-Free Supercapacitors;*** Licentiate Thesis 125: Mid Sweden University, ISSN 1652-8948; ISBN, 978-91-88025-74-6 (2016)
- Forsberg, Viviane; ***Liquid Exfoliation of Molybdenum Disulfide for Inkjet Printing;*** Licentiate Thesis 123: Mid Sweden University, ISSN 1652-8948; ISBN 978-91-88025-71-5 (2016)

Photo: Nicklas Blomquist and supervisor professor Håkan Olin in the Licentiate seminar in Engineering Physics.

FSCN in numbers





New employees and new positions

- **Carolina Costa** is new PhD Student in the Surface and Colloid Engineering group with prof. Magnus Norgren and Håkan Edlund as supervisors.
- **Italo Sanhueza** is new researcher in the Organic Chemistry group with prof. Armando Cordova as group manager.
- **Birgitta Engberg** is new associate professor/docent in chemical engineering.
- **Jan Pourian** is new lecturer in the program Energy Engineering.
- **Sara Norström** is back at Mid Sweden University again after two years post doc in Umea University. She works in the research group Analytical Chemistry – Forest and Environment together with prof. Dan Bylund.
- **Sohan Sarangi** is new PhD Student in the research group Complex Materials with prof. Tetsu Uesaka as supervisor.
- **Roland Bäck** is new researcher in the research group High Yield Pulping Technology instead of Louise Logenius while she is on parental leave.
- **Reidar Hagner** is new researcher in the research group Materials Physics. He work part time in the research project KM2.

The career program 2015-2017

Mid Sweden University conducts a career program for recently graduated researchers. The program began in spring 2015. Christina Dahlström, Kristina Göransson, Ida Svanedal, Erika Wallin and Fredrik Carlsson from department NAT and CHE (FSCN) participate in the career program. Part of their research will be on other universities abroad. The program will last for two years.

Business Innovation Seminars

During 2015 we have arranged the monthly seminars Business Innovation Seminar in cooperation with the research centre STC and the innovation clusters BioBusiness Arena and Fiber Optic Valley. The seminars were also streamed on our website and the YouTube channel for Mid Sweden University. Follow the seminars online and afterwards on our website **www.miun.se/seminars.**

Table Guest speakers in 2016

Guest speakers	Date	Website/YouTube watch
Marita Niemelä, Valmet	4 Feb 2016	870
Inge Friberg and Martin Grönblad, Bucher Emhart Glass	3 Mar 2016	131
Björn Vedin and Carina Eriksson, Akzo Nobel Pulp and Performance	7 April 2016	116
Thore Lindgren, SEKAB	3 Sep 2016	62
Mats Nordlander, SCA Paper	3 Nov 2016	106
Andreas Nordstrand, Dockstavarvet	8 Dec 2016	38

Photo: Britta Andres PhD Student in the Materials Physics group.

Transformative Technologies

Transformative Technologies is a research environment formed of the research centres STC and FSCN that collaborate with a mixture of forest and ICT industry. Transforming the Industrial Ecosystem describes a vision for regional renewal and growth. It combines the industrial strengths of the Sundsvall region with the dynamic force that Mid Sweden University represents. Since 2011, the Knowledge Foundation has been supporting us through the program research environment (KK Miljö).

Research for growth and renewal

The university attracts and educates young people to work in the region and sustain industrial competitiveness. Through its research and knowledge transfer the university facilitates renewal. When acting in symbiosis, the current industrial core and new businesses at its edges can become an effective ecosystem that continuously renews itself.

One of the goals of our research is to contribute to growth, transformation and innovation for the companies within the Transformative Technologies. Together with municipalities and companies we work with a regional agenda for research, innovation and education. The common agenda promotes cooperation within the region. Key partners for the development is the innovation clusters BioBusiness Arena, Fiber Optic Valley and Processum.

The Vision Transforming the Industrial Ecosystem

The aim of the vision Transforming the Industrial Ecosystem is to contribute to development and growth from different perspectives. Transformation is important for the forest industries who need to develop new products and new business areas. Information technology is a growth engine that creates new products and services. By linking these two industries, we create an industrial ecosystem with particularly exciting prospects regionally and nationally. Co-production is the central point of many of the research projects within the research environment, which means that project teams have both academic and industrial members. It provides dynamic and interesting environments that can identify solutions and thereby driving growth in both established and new companies.

The research program of Transformative Technologies consists of six strategic actions that focus on different industrial aspects of improved competitiveness and renewal:

- **e2mp** – Manufacturing in industrial scale
- **FORIC** – Competence development for regional renewal
- **EISS** – Process control and monitoring
- **KM2** – Large surfaces for electronic functionality
- **XGeMS** – Environment into the control loop
- **CellFUNC** – Cellulose to new uses

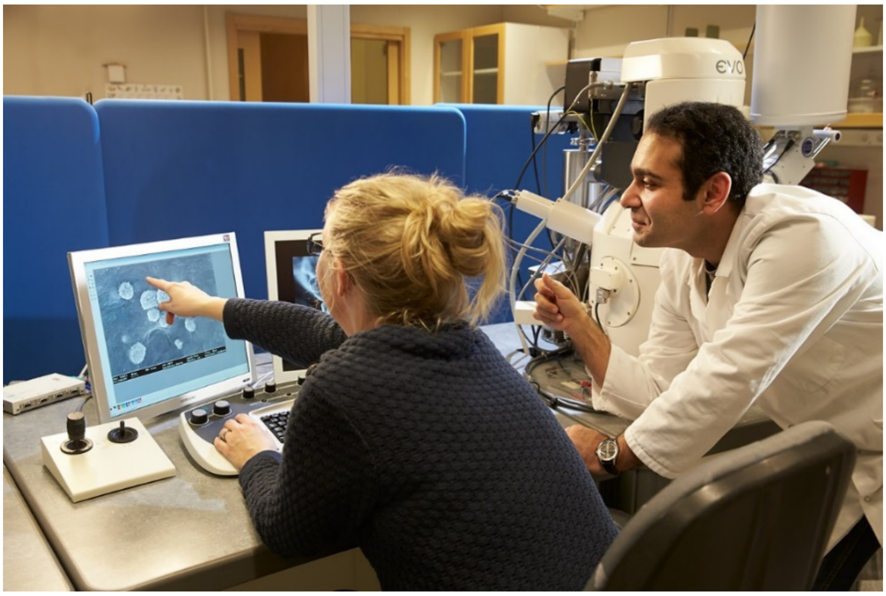


Photo: Dr. Christina Dahlström and PhD Student Alireza Eivazi works with the SEM Microscope.

Research Groups

We have eight research groups at FSCN.

1. **Bioenergy** – The Bioenergy gasification research group is focused on synthesis gas ("syngas") production from biomass for automotive fuel production. The group manager is Asso. Prof. Wennan Zhang. **Group members:** Ulf Söderlind, Kristina Göransson, Zhe Zhang.

2. **Complex Materials** - The heart of research in complex materials group is in unfolding nature's beautiful trick as a complex system, and in deploying it to redefine our current material design practices. The group manager is prof. Tetsu Uesaka. **Group members:** Amanda Mattsson, Sohan Sarangi, Shakawath Hossain, Per Bergström, Kaarlo Niskanen

3. **Digital Printing Centre** – This research group is located in Örnsköldsvik. The group manager is Mattias Andersson.

4. **Eco Chemistry** - The main research interests of the Eco-Chemistry group concerns synthesis, extraction and analysis of natural products. The group manager is prof. Erik Hedenström. **Group members:** Fredrik Andersson, Kerstin Sunnerheim, Erika Wallin, Joel Ljunggren, Rizan Rahmani, Lina Viklund

5. **High Yield Pulping Technology** - Research focused on raw material, process technology and new or improved products and qualities for pulps and paper. The group manager is prof. Per Engstrand. **Group members**: Myat Htun (part time), Hans Höglund (part time), Per Gradin, Torbjörn Carlberg, Thomas Granfeldt (part time), Magnus Paulsson (part time), Lennart Salmén (part time), Olof Björkqvist, Birgitta Engberg, Jan-Erik Berg, Olof Ferritsius, Rita Ferritsius (part time), Louise Logenius, Sven Norgren, Gunilla Pettersson, Staffan Nyström (part time), Christer Sandberg (part time), Sinke Henshaw Osong, Folke Österberg (part time), Majid Alimadadi, Roland Bäck.

6. **Materials Physics** - Our research concerns materials and we conduct research for advanced paper materials and functional applications. The group manager is prof. Håkan Olin. **Group members:** Sven Forsberg (part time), Joakim Bäckström (part time), Mikael Gulliksson (part time), Lars Norin, Magnus Hummelgård, Jonas Örtegren, Renyun Zhang, Nicklas Blomquist, Martin Olsen, Britta Andres, Kristoffer Karlsson, Lena Lorentzon, Morteza Abdipour, Diogo Volpati, Santosch Limaye, Thomas Öhlund, Viviane Forsberg, Reidar Hagner.

7. **Organic Chemistry** - The research interest of the organic chemistry group focuses around green catalysis and in particular the field of organic catalysis. The group manager is prof. Armando Cordova. **Group members**: Samson Afewerki, Rana Alimohammadzadeh, Italo Sanhueza.

8. **Surface and Colloid Engineering** - The research in our group Surface and Colloid Engineering is focused on the following two main areas; Biomaterials and Metal chelation. The group manager is prof. Magnus Norgren. **Group members:** Björn Lindman, Håkan Edlund, Bo Westerlind, Christina Dahlström, Ida Svanedal, Ran Duan, Alireza Eivazihollagh, Jiayi Yang, Carolina Costa.

Photo: Staffan Nyström, Gunilla Pettersson and Birgitta Engberg works in the laboratory with dynamic material testing – using the encapsulated split-Hopkinson pressure bar device.

Research projects 2016

Research project	Project leader
2D Inks	Sven Forsberg
Advanced high yield pulp for paperboard	Gunilla Pettersson
Cello – Native cellulose´s interplay in materials and dispersions	Magnus Norgren
Cellulose in correct format for optimized energy storage	Christina Dahlström
Compac – Plasticized cellulose composites for packaging applications	Bo Westerlind
e2mp-rp – energy efficient mechanical pulping research profile, 9 sub-projects: • *Bat 2012* • *Chip pre-treatment DD-refining* • *Efficient LC-refining* • *Pre-treatment strategies in high yield pulping* • *Refining of softened TMP fibres* • *Chip-refining efficiency* • *Fibre development models* • *Maximized fibre wall swelling in TMP & CTMP refining* • *Quantifying mechanical treatment during chipping*	Per Engstrand
e2cmp - Eco-friendly efficient chemi-mechanical system for sustainable packaging materials, 3 sub-projects: 1. *Preserved fibre morphology by fibre softening and chip refining intensity optimization.* 2. *Maximized fibre separation and increased fibre surface at preserved bulk by optimized low consistency refining.* 3. *Improved fibre adhesion of bulky CTMP fibres by means of metal-free catalysis.*	Per Engstrand
Fibre network design: Applications to hygiene products	Tetsu Uesaka
Foric – Forest as a resource industrial research college, More information on page 18.	Per Engstrand, Olof Björkqvist

Gröna Pro - Green chemicals from forest and forest products	Erik Hedenström
Högox – Highly selective electrocatalysts for anodic oxidation	Joakim Bäckström
Keep the strength	Rita Ferritsius
Keps - Kinetic energy storage in paper-based supercapacitors	Sven Forsberg
KM2 – Innovative green energy, 7 sub-projects: • Solar energy • Wind energy • Supercapacitors • Batteries • Large displays • Green street light • Materials and Innovations Laboratory MILAB	Håkan Olin
LEAP – Large-area energy application platform, 3 sub-projects: 1. Glass-on-paper 2. Printed conductor 3. Thermoelectric generators	Håkan Olin
Ligno- and nanocellulose materials, new sustainable products	Armando Cordova
Light-weight structural composites from fibre-based materials, reliability-based design	Tetsu Uesaka
Lithium Ion Batteries	Joakim Bäckström
ModDD – Process modeling and new technical solutions for increased production rate	Birgitta Engberg
Modulit – monolistiskt integrerade energilagringsmoduler	Sven Forsberg
Morphology studies on future biocomposite	Christina Dahlström
Novocell	Magnus Norgren
Ocxis - Operation and change of complex industrial systems	Olof Björkqvist
Paper solar cells	Håkan Olin
Manufacturing of short-fibre yarn	Bo Westerlind
Mechanics of Decubitus ulcers in Human Skin	Tetsu Uesaka
Surface modified CTMP for strong packaging materials	Sven Norgren
TransAlgae	Wennan Zhang
Transform	Magnus Norgren

FORIC – Competence development for regional renewal

Foric is a graduate school in close cooperation with industries and companies where PhD students are employed by the companies and do their research studies part time. Our aim is to create a network of value streams around bio-based industries and close companies and increase the competitiveness of the partner companies. These research projects and researchers started in 2014. We are planning for second intake and start of new research projects in 2017. Read more on **www.miun.se/foric**.

Research project	PhD Student	Company
Wood preservative treatment and modification techniques; identification, evaluation and assessment of barriers and key success factors for large-scale commercialization	Jonas Johansson	SCA Timber AB
New use of bio-sludge from pulp and paper industries	Robert Norgren	Ragn-Sells AB
Methane measurement system and analysis	Bakhram Gaynullin	SenseAir AB
Technical and economical systems modelling of a mechanical pulp based bio refinery	Alexander Hedlund	FrontWay AB
Improved fines material control	Mathias Lundberg	PulpEye AB
Modified fibre process for improved final product properties	Hafizur Rahman	SCA Forest Products AB
Integrated energy solutions	Anna-Karin Stengard	Sundsvall Energi AB
Industrially feasible methods for production of nanocellulose for chemical pulps	Carl Moser	Valmet AB
Connecting high yield pulp properties with functional product properties	Olof Ferritsius	StoraEnso AB
Fibrillar chemical pulp fines to enhance paper board strength	Elisabeth Björk	Innventia AB
Value creating and efficiency in wood supply chains	Magnus Larsson	Skogforsk et al.

Conferences

Tappi Advanced coating symposium

On October 4-6 2016 some of our researchers joined the research Conference Tappi Advanced coating symposium at Innventia in Stockholm. The programme included sessions covering sustainable barrier coatings, new coating structure analytical techniques and modeling of coating structure. The keynote speaker was Anna Jonhed, R&D Director of BillerudKorsnäs (photo). Christina Dahlström, Sven Forsberg, Britta Andres, Magnus Engholm and Enkeleda Balliu participated from Mid Sweden University.

IMPC International Mechanical Pulping Conference 2016

The International Mechanical Pulping Conference, organized by the Pulp and Paper Technical Association of Canada took place from 26th September to 28th September 2016 at the Hyatt Regency Jacksonville Riverfront in Jacksonville, USA. The conference covered areas like Pulping & bleaching, engineering & mill reliability, energy & water management, print, packaging & converting. Gunilla Pettersson, Sven Norgren, Birgitta Engberg, Jan-Erik Berg, Per Engstrand, Olof Ferritsius, Rita Ferritsius and Christer Sandberg participated from Mid Sweden University.

Business Innovation Day 2016

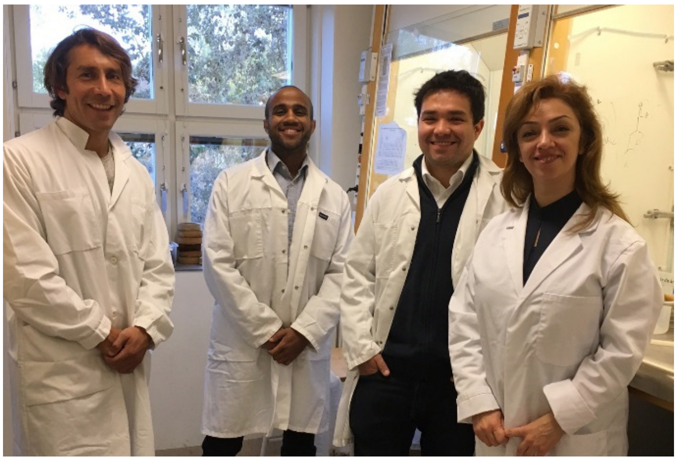
On October 17 we arranged Business Innovation Day at campus Sundsvall. This is a day where companies can send in challenges they are facing and meet researchers to discuss solutions. This year we had 12 company challenges to discuss. We also had an open guest Seminar with

Jackie Kothbauer on the stage in Grönborg, talking about branding and social media.

Science Innovation Day 2016

Every year in the middle of October we arrange the conference Science & Innovation Day in Sundsvall. The conference is a cooperation between the research centres STC and FSCN and the innovation clusters Fiber Optic Valley, SP Processum and BioBusiness Arena. 2016 gathered approx. 200 persons from academia and companies in the region to discuss innovation, research and future cooperation. The keynotespeakers were Maria Stromme, professor in nanotechnology from Uppsala University, Frida Boisen, digital manager at Bonnier and Erik Kruse from Ericsson. The researchers from STC and FSCN presented their research results in parallel sessions and there were an exhibition area with posters to present research. See all the seminars on our website: **www.miun.se/fscn.**

Awards



The researchers Samson Afewerki and Armando Córdova got SKAPA Foundation Development Scholarship in Västernorrland 2016. As winners of the regional final competition they will get 15 000 sek reward for the development of a unique and environmentally friendly method to selectively decompose lignin and transform it into products with a higher market value, such as liquid biofuels, polymers and pharmaceuticals.

The researchers' innovative technology uses non-toxic organic catalysts and its directly implementable in existing industrial scale production. The technology will benefit the paper industry, forest owners and fuels companies.

Ekmandagarna in Stockholm 2016

Our PhD Student Amanda Mattsson is the Winner of the Gunnar Sundblad session for young researchers on Ekmandagarna in Stockholm 2016. She had eight competitors from Chalmers, KTH, Karlstad and Umeå. The concept were Pecha Kucha and the PhD students used 20 slides in 20 sek each to describe their research. The prize is a travel-scholarship of 50.000 sek.

Accomplished PhD Degrees

Doctoral Thesis

Improved energy efficiency in mill scale production of mechanical pulp by increased wood softening and refining intensity

Erik Nelsson

This thesis focuses on the electric energy efficiency of single stage double disc refining for production of printing grade mechanical pulp from Norway spruce wood chips. The thesis is based on the hypothesis, that more energy efficiency refining can be attained by balanced increases of wood softening and refining intensity. Five mill scale trials were performed where wood softening and refining intensity was varied by applying or changing the following process parameters and variables:

- Chip pretreatment/impregnation with water
- Low dosages of sodium sulfite (Na_2SO_3) added to impregnation
- Temperature and retention time in the atmospheric preheater bin
- Refining temperature (housing pressure)
- Feeding segment design combined with increased production rate

By combining suitable increases in wood softening and refining intensity, it was possible to reduce the specific electric energy consumption in refining by 15% (~290 kWh per bone dry ton (bdt)) while preserving important pulp properties within ±5%, compared to the standard double disc refining process. This was done by combining chip impregnation, using an addition of 0.36% (on bone dry basis) sodium sulfite, with a new feeding segment design which enabled 25% higher production rate.

When using the new feeding segment design at an increased production rate at unchanged wood softening, it led to reduced fiber length and increased sheet light scattering coefficient at certain tensile index, compared with the standard segment design at normal production rate. This is consistent with the effects normally seen when the refining intensity is increasing. The specific electric energy consumption was 8% lower at a tensile index of 43.5 Nm/g (on Rapid Köthen laboratory sheets) compared to refining at lower intensity using the standard segment design at normal production rate.

Mechanical chip pretreatment with subsequent water impregnation showed a reduction in specific electric energy consumption of 6% (~120 kWh/bdt). When chip impregnation was applied in a later trial with a milder chip compression, it led to increased wood softening seen as better preserved fiber length and reduced light scattering coefficient. This resulted in a reduction in tensile index at certain specific electric energy consumption when applied with the standard refining condition but to an increase in tensile index when applied with refining at higher intensity using the feeding segment design at higher production rate.

An addition of 1.2% sodium sulfite during impregnation led to a sulfonate content of pulps of ~0.28% (as Na_2SO_3 equivalents, including post sulfonation) and an average increase in tensile index of about 8.3 Nm/g, when compared to unsulfonated pulps at certain specific electric energy consumption. The increase in tensile index correlated with increased delamination and internal fibrillation of fibers (measured by Simon's staining), which indicate that the increase in tensile index for sulfonated pulps was a result of improved fiber flexibility and collapsibility. The reduction in disc gap at certain specific electric energy consumption in refining due to an increased wood softening after sulfonation may explain the increase in delamination and internal fibrillation for sulfonated pulps. The smaller disc gap probably led to a more intense refining, i.e. loading at higher deformation rates due to a higher degree of deformation in bar crossings.

Different temperatures (80 vs. 97°C) and retention times (6 vs. 9 min.) in the atmospheric preheater bin were studied. This showed that the lower temperature and shorter retention time was beneficial for the tensile strength and light scattering of pulp when applying low dosage sodium sulfite pretreatment. This was most likely a result of too high degree of wood softening prior to defibration in the breaker bar zone when combining low dosage sodium sulfite pretreatment with the higher preheating bin temperature at longer retention time.

Different refining temperatures (4.6 and 6.4 bar(g) refiner housing pressure) were evaluated both without and with low additions (0.6% and

1.2%) of sodium sulfite. Raising the refining temperature increased tensile index by 3.2 Nm/g and the addition of 1.2% sodium sulfite by 8.6 Nm/g. The combined increase (~12 Nm/g) was similar to the effect of increasing the specific electric energy consumption by 380 kWh/bdt, when comparing pulps at equal tensile index. However, the pulps produced with increased refining temperature and sodium sulfite addition had lower light scattering coefficient at certain tensile index. The combination of increased refining temperature and addition of 0.6% sodium sulfite was interesting and resulted in pulp with higher tensile index, light scattering coefficient and brightness together with lower shives content at certain specific electric energy consumption, compared with pulp produced at the lower refining temperature without addition of sodium sulfite.

Finally, an implementation of the technology presented here is discussed in relation to the Braviken mill (Holmen Paper AB, Norrköping, Sweden) concerning reduction in electric energy consumption and steam recovery. The technology has potential to reduce the electrical energy use by ~100 GWh/year at the Braviken paper mill, where this study was performed.

ISBN 978-91-88025-59-3

Doctoral Thesis

Mechanical pulp-based nanocellulose: Processing and applications relating to paper and paperboard, composite films and foams

Sinke Henshaw Osong

This thesis deals with processing of nanocellulose originating from pulps, with focus on mechanical pulp fibres and fines fractions. The nanocellulose materials produced within this research project were tested for different purposes ranging from strength additives in paper and paperboard products, via composite films to foam materials. TAPPI (Technical Association of Pulp & Paper Industry) has recently suggested a standard terminology and nomenclature for nanocellulose materials (see paper I). In spite of that we have decided to use the terms nano-ligno-cellulose (NLC), microfibrillated cellulose (MFC), nanofibrillated cellulose (NFC) and nanocellulose (NC) in this thesis. It is well-known that mainly chemical pulps are used as starting material in nanocellulose production. However, chemical pulps as bleached sulphite and bleached kraft are quite expensive. One more cost-effective alternative can be to use fibres or fines fractions from thermo-mechanical pulp (TMP) and chemi-thermomechanical pulp (CTMP).

In paper II-IV, fractionation has been used to obtain fines fractions that can easily be mechanically treated using homogenisation. The idea with this study was to investigate the possibility to use fractions of low quality materials from fines fractions for the production of nanocellulose. The integration of a nanocellulose unit process in a high-yield pulping production line has a potential to become a future way to improve the quality level of traditional products such as paper and paperboard grades.

Paper III describes how to utilise the crill measurement technique as a tool for qualitative estimation of the amount of micro- and nano-material produced in a certain process. The crill values of TMP- and CTMP-based nanocelluloses were measured as a function of the homogenisation time.

Results showed that the crill values of both TMP-NLC and CTMP-NLC correlated with the homogenisation time. In Paper V pretreating methods, hydrogen peroxide and TEMPO are evaluated. Crill measurement showed that hydrogen peroxide pretreatment (1% and 4%) and mechanical treatment time did not improve fibrillation efficiency as much as expected. However, for TEMPO-oxidised nanocelluloses, the crill value significantly increased with both the TEMPO chemical treatment and mechanical treatment time. In paper V-VII TEMPO-mediated oxidation systems (TEMPO/NaBr/NaClO) are applied to these fibres (CTMP and Sulphite pulp) in order to swell them so that it becomes easy to disrupt the fibres into nanofibres with mechanical treatment.

The demand for paperboard and other packaging materials are steadily increasing. Paper strength properties are crucial when the paperboard is to withstand high load. A solution that are investigated in papers IV and VI, is to use MFC as an alternative paper strength additive in papermaking. However, if one wish to target extremely higher strength improvement results, particularly for packaging paperboards, then it would be fair to use MFC or cationic starch (CS). In paper VI CS or TEMPO-based MFC was used to improve the strength properties of CTMP-based paperboard products. Results here indicate significant strength improvement with the use of different levels of CS (i.e., 20 and 10 kg t^{-1}) and 5% MFC. The strengthening impact of 5% MFC was approximately equal to that of 10 kg t^{-1} of CS.

In paper VII, NFC and nanographite (NG) was used when producing composite films with enhanced sheet-resistance and mechanical properties. The films produced being quite stable, flexible, and bendable. Realising this concept of NFC-NG composite film would create new possibilities for technological advancement in the area of high-yield pulp technology. Finally, in paper VIII, a new processing method for nanocellulose is introduced where an organic acid (i.e., formic acid) is used. This eco-friendly approach has shown to be successful, a nanocellulose with a uniform size distribution has been produced.

ISBN 978-91-88025-64-7

A selection of researchers

Magnus Paulsson
Adjunct Professor

(sponsored by Akzo Nobel)

The main activities in 2016 have been as an assistant supervisor to the Ph.D. student Erik Nelsson (FSCN) that defended his thesis on April 21, a member in the project group for the project "Bevarad massakvalitet efter raffinering för att kunna sänka elenergiinsatsen" (Maintained pulp quality after refining in order to lower the electrical energy input, partly financed by the Swedish Energy Agency) and a lecturer at Cellulose Technology (M.Sc. course, advanced level, CTH). I have also served as a member of the Formas review panel for Resource Efficient Products and Processes, as a member of the review editorial board of Frontiers in Bioenergy and Biofuels, and as a board member for the Forest Products Industry Research College (FPIRC). The research work has resulted in one submitted manuscript and two published papers (listed below).

Publications

- Hellström P. , Heijnesson Hultén A. , Paulsson M. , Håkansson H. and Germgård U. (2016): ***A comparative study of enzymatic and Fenton pretreatment applied to a birch kraft pulp used for MFC production in a pilot scale high-pressure homogenizer.*** Tappi J. 15(6), 375-381.
- Nelsson E. , Sandberg C. , Svensson-Rundlöf E. , Paulsson M. , Granfeldt T. , Engberg B. and Engstrand P. (2016): ***Mill scale production of TMP with double disk refining – The effects of a mild sulfonation, atmospheric preheating and refining temperatures.*** Proc. 29th Int. Mech. Pulp. Conf., Jacksonville, FL, USA, September 26-28, 11pp.

Britta Andres, PhD Student

Electrodes for Electric Double-Layer Capacitors

During 2016, I have mainly worked with electrode design and composition for electric double-layer capacitors (EDLCs). I have published one article about electrode mass balancing in EDLCs. In this article I have demonstrated that adjusting the mass loading of EDLC electrodes improves the capacitance of the devices and reduces the material usage.

Furthermore, I have focused on the composition of EDLC electrodes and tried to find a good combination of different types of graphite and nanocellulose for EDLC electrodes. The SEM images below show the surface of a composite that consists of graphite, activated carbon and cellulose nanofibers. One can clearly see the layered structure of the graphite flakes, the spherical shape of the activated carbon, and the cellulose nanofiber network that cross-links the active material.

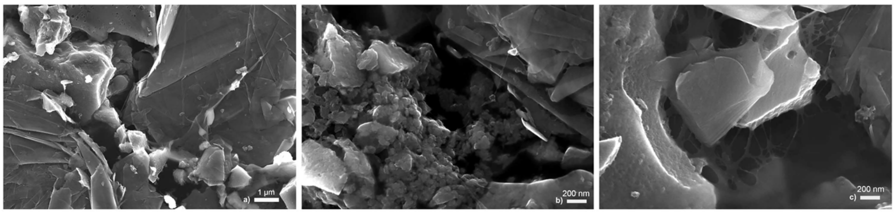


Fig: Structure of the surface of a composite that consists of graphite, activated carbon and cellulose nanofibers. The images were taken with a field emission scanning electron microscope; a) magnification of 25000 ×; b) and c) magnification of 100000 ×.

Publications

- Andres, B. , Engström, A. , Blomquist, N. , Forsberg, S. , Dahlström, C. & Olin, H. (2016). ***Electrode Mass Balancing as an Inexpensive and Simple Method to Increase the Capacitance of Electric Double-Layer Capacitors.*** *PLoS ONE,* vol. 11: 9, ss. 1-12.
- Blomquist, N. , Engström, A. , Hummelgård, M. , Andres, B. , Forsberg, S. & Olin, H. (2016). ***Large-Scale Production of Nanographite by Tube-Shear Exfoliation in Water.*** *PLoS ONE,* vol. 11: 4
- Osong, S. H. , Dahlström, C. , Forsberg, S. , Andres, B. , Engstrand, P. , Norgren, S. & Engström, A. (2016). ***Nanofibrillated cellulose/nanographite composite films.*** *Cellulose (London),* vol. 23: 4, ss. 2487-2500.
- Forsberg, V. , Zhang, R. , Joakim, B. , Dahlström, C. , Andres, B. , Norgren, M. , Andersson, M. , Hummelgård, M. & et al. (2016). ***Exfoliated MoS2 in Water without Additives.*** *PLoS ONE,* vol. 11: 4
- Forsberg, V. , Zhang, R. , Andersson, H. , Bäckström, J. , Dahlström, C. , Norgren, M. , Andres, B. & Olin, H. (2016). ***Liquid Exfoliation of Layered Materials in Water for Inkjet Printing.*** *Journal of Imaging Science and Technology,* vol. 60: 4, ss. 40405-1-40405-7.

Nicklas Blomquist,
PhD Student

There is great demand for energy-efficient, environmentally sustainable and cost-effective electrical energy storage devices. One important aspect of this demand is the need for automotive electrification to achieve more energy-efficient transportation at a reasonable cost, thus supporting a fossil-fuel-free society. Much of the research in this area has been conducted in the field of battery technology, but the need for quick storage devices such as supercapacitors is growing. Due to the excellent ability of supercapacitors to handle short peak power pulses with high efficiency along with their long lifetime and superior cyclability, the applications for supercapacitors stretch from small consumer electronics to electric vehicles and stationary grid applications. However, the cost of supercapacitors is a significant issue for large-scale commercial use, leading to a need for sustainable, low-cost materials and simplified manufacturing processes. An important way to address this need is to develop a cost-efficient and environmentally friendly large-scale process to produce highly conductive carbon nanoparticles, such as graphene and nanographite.

Research results 2016

During 2016 I defended my licentiate thesis: Large-Scale Nanographite Exfoliation for Low-Cost Metal-Free Supercapacitors. In this thesis I present a novel process to mechanically exfoliate industrial quantities of graphene and nanographite from graphite in an aqueous environment, with low energy consumption and at controlled shear conditions. The process is based on hydrodynamic tube shearing in laminar flow and is able to produce nanometer-thick and micrometer-wide flakes of nanographite.

Figure 1: The hydrodynamic tube shear system (left) and its cooperating stirrer (right).

This system has a production rate exceeding 500 g/h and an energy consumption of approximately 10 Wh/g exfoliated material. The design of the process allows for scaling to even higher production rates using an improved pump and multiple tubes in parallel.

The exfoliated material can be used for production of highly conductive and robust carbon composites, based on the addition of cellulose nanofibrills (CNF) during production; suitable for the large-area coating of electrodes in applications ranging from supercapacitors and batteries to printed electronics and solar cells.

I also propose a novel aqueous low-cost and metal-free supercapacitor concept, based on the use of graphite foil as the current collector and a mixture of graphene, nanographite, simple water purification carbons and cellulose nanofibrills as the electrodes. The electrodes were coated directly on the graphite foil using casting frames and the supercapacitors were assembled in a pouch-cell design. The supercapacitors possessed approximately half the specific capacitance of commercial units but achieved a material cost reduction of more than 90 %, demonstrating an environmentally friendly low-cost alternative to conventional supercapacitors.

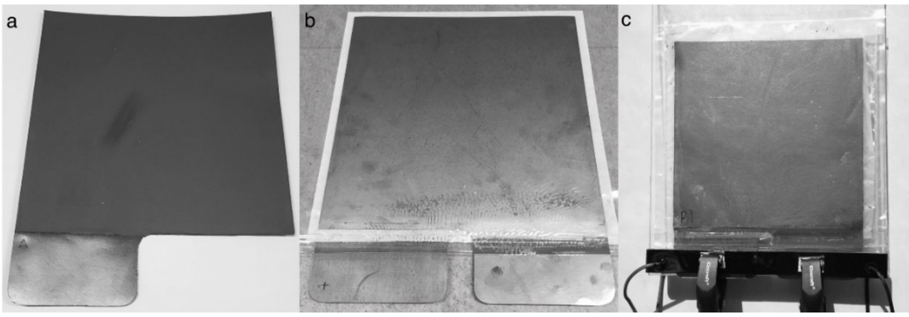


Figure 2: (a) 200 mm x 200 mm electrode-coated graphite foil with a 90 mm x 50 mm contact, (b) the assembled SC pouch-cell device with two electrode-coated graphite foils and a greaseproof paper separator between them, (c) the electrolyte-filled SC pouch-cell device connected to a four-point-probe contact.

Publications

- Blomquist, Nicklas. ***Large-Scale Nanographite Exfoliation for Low-Cost Metal-Free Supercapacitors***. 2016. Licentiate thesis: 125. Mid Sweden University. ISBN: 978-91-88025-74-6
- Blomquist, N. , Engström, A. , Hummelgård, M. , Andres, B. , Forsberg, S. & Olin, H. (2016). ***Large-Scale Production of Nanographite by Tube-Shear Exfoliation in Water.*** *PLoS ONE,* vol. 11: 4
- Andres, B. , Engström, A. , Blomquist, N. , Forsberg, S. , Dahlström, C. & Olin, H. (2016). ***Electrode Mass Balancing as an Inexpensive and Simple Method to Increase the Capacitance of Electric Double-Layer Capacitors.*** *PLoS ONE,* vol. 11: 9, ss. 1-12.

Dr. Ida Svanedal

Research results 2016

I am a researcher in the group Surface and colloid engineering. My research interest is in physical chemistry and particularly in surface and colloid chemistry. I am mainly working within two fields; dissolution and regeneration of cellulose polymers, and chelating surfactants. My focus is on fundamental understanding of the physicochemical properties of these materials. Increased knowledge of dissolution and regeneration of cellulose and cellulose derivatives in aqueous based solvents will enhance the possibilities of using wood-based cellulose for instance in textile and composite materials.

The dual functionality of chelating surfactants makes them interesting from a technology point of view. The chelating moiety is designed to capture specific metal ions, while the surface active part provides a way of separating the formed complex from a water solution. These molecules show very interesting surface properties due to their large and highly charged head groups. Neutron and X-ray reflection measurements, which we performed at NIST (national institute of standards and technology) USA, was used to study the adsorption behavior of these molecules. The purpose was to examine the correlation between surface tension and surface excess concentration as well as constructing a model of the adsorbed layer. We found that the adsorption of chelating surfactants at an air/water interface could be well described by a two-layer model, with the hydrocarbon tails organized in an upper layer and the hydrated headgroups in a lower layer. The unusually thick headgroup layer correlates well with the molecular structure of the chelating surfactants. These results were published in the journal Langmuir.

During the year I have also participated in a research leader training, organized by the career program at Mid Sweden University, with meetings over a couple of days every second month.

The main part of 2016 I was however on parental leave taking care of my little son.

Dr. Christina Dahlström

Morphology studies on future biocomposite

Research results 2016

My research interest is cellulosic materials, both in the form of dissolved/regenerated cellulose and nanocellulose, and their composite materials. In the supercapacitor project, my part is to understand more about the role of cellulose in the electrodes.

In October I visited Prof. Alberto Salleo's group at Stanford University and worked together with Associate Prof. Gregorio Faria to measure ion mobility in cellulose films. The films were prepared in cooperation with Prof. Wågberg at KTH. This work will be continued in 2017 and is part of the Mid Sweden University's program for "Future research leaders", where travelling abroad to work in another research group is part of the activities.

Approved applications for funding during 2016 was from Åforsk (0.45 MSEK 2016-2017) and from the KK-foundation (1.4 MSEK 2017-2019). In the Åforsk project we are studying how the type of cellulose is affecting the graphite dispersion stability, strength of the electrode and electronic performance. We have a matrix from nanocellulose up to pulp fibres for complete comparison. The KK-foundation project is within our Master program.

I am the Chair of the TAPPI Coating Fundamental Committee and during 2016, the main task was to plan and arrange the TAPPI Advanced Coating Symposium at Innventia, Stockholm. We also had a presentation at this Symposium, together with Prof. Martti Toivakka's group from Åbo Akademi University. The effect of calendering, particle type and coat weight on electrical properties was studied on conductive coatings. The most important property for the electronic performance was coat weight, but also calendering decreased the resistance to a large extent. Figure 1 shows a scanning electron microscopy image of a surface where the different particle types used are visualized, flaky nanographite and spherical carbon black.

A lot of effort has been made on tender processes during 2016 to build up and establish Material and Innovation Laboratory (MILAB). MILAB is part of the project "KM2 – Green innovative energy". A high resolution scanning electron microscope (SEM), a sputter coater and a particle analyzer was ordered during 2016.

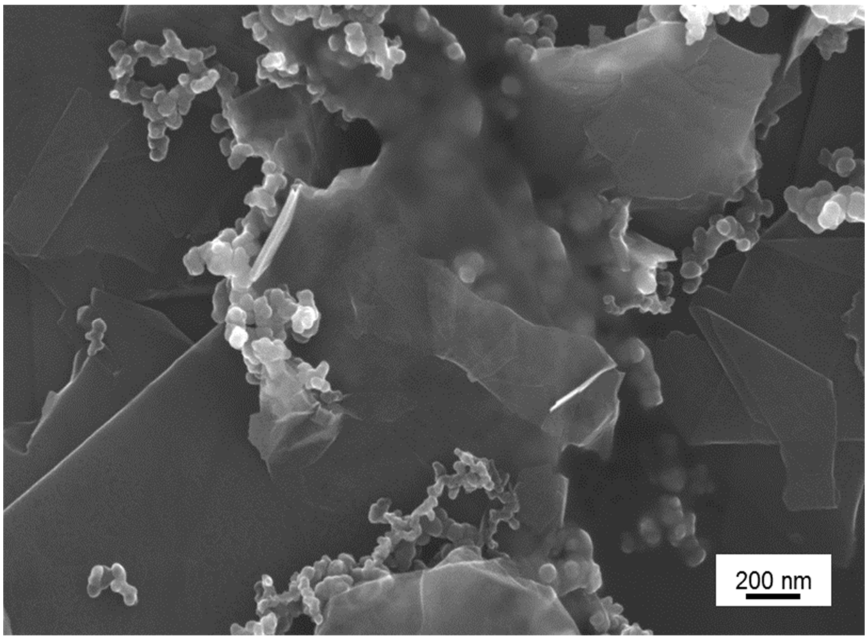


Figure 1. *Scanning electron microscopy image of a coating surface. The flaky pigments are nanographite and the smaller spherical pigments are carbon black.*

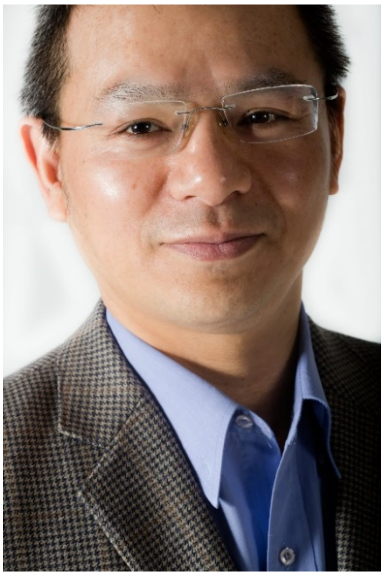
Publications

- Andres, B. , Engström, A-.C. , Blomquist, N. , Forsberg, S Dahlström, C. , and Olin, H; ***Electrode mass balancing as an inexpensive and simple method to increase the capacitance of electric double-layer capacitors***, PloS One, vol. 11:9, pp 1-12, 2016
- Henshaw Osong, S. , Dahlström, C. , Forsberg, S. , Andres, B. , Engstrand, P. , Norgren, S. , Olin, H. , Engström, A.-C. ; ***Nanofibrillated cellulose/nanographite composite films***, Cellulose, Volume 23, Issue 4, pp 2487–2500, 2016
- Forsberg, S. , Kumar, V. , Engström, A-.C. , Nurmi, M. , Dahlström, C. , and Toivakka, M. ; ***Effect of calendering and coating formulations on conductivity in paper-based electrodes***, TAPPI

Advanced Coating Symposium 2016, 4-6 October, Stockholm, Sweden.

- Forsberg, V. , Zhang, R. , Andersson, H. , Bäckström, J. , Dahlström, C. , Norgren, M ., Andres, B. and Olin, H.; ***Liquid Exfoliation of Layered Materials in Water for Inkjet Printing***, J. Imaging Sci. Technol. Vol. 60:4, 2016
- Forsberg, V. , Zhang, R. , Joakim, B. , Dahlström, C. , Andres, B. , Norgren, M. , Andersson, M. Hummelgård, M. & et al. ***Exfoliated MoS2 in Water without Additives.*** PLoS ONE, vol. 11: 4, 2016

Wennan Zhang, Docent, Associate Professor



Research results 2016

Paper 1

Zhang, W., Henschel, T., Söderlind, U., Khanh-Quang Tran and Xu Han; ***"Evaluation of various biomass feedstocks by using thermogravimetric and online gas analysis",*** Energy Procedia, in press, (2016)

In this work, the biomass property is evaluated based on pyrolysis behavior of biomass fuels by means of TGA and online gas analysis. Wood, sawdust, pine bark, peat, straw, black liquor and microalgae are chosen as the biomass feedstocks for the pyrolysis study. The measurement results show high volatile content for algae and black liquor (around 85%) and low volatile content for pine bark and peat (around 69%). Differently from woody biomass, the DTG curve of straw has a single dominant peak at much lower temperature, which suggests a dominant component of hemicellulose in biomass, while algae and peat have a broader temperature spectrum of devolatilization but much lower peak temperature. CO2 is released first and H2 later in the pyrolysis process for all biomass feedstocks, whileas the peak of CO formation follows CO2 formation trend for most feedstocks used, except for peat and pine bark which give a peak later at high temperature. This indicates secondary reactions of tar cracking, steam reforming and char gasification.

Paper 2

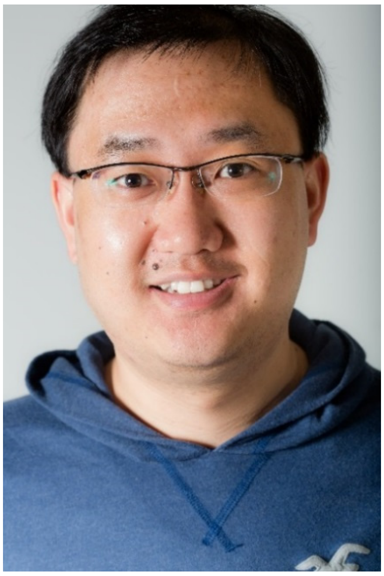
Zhang, Zhe, Ningchen Tian, Wennan Zhang, Xiaodong Huang, Le Ruan and Ling Wu, ***"Inhibition of carbon steel corrosion in phase-change-materialssolution by methionine and proline"***, Corrosion Science 111, 675–689 (2016)

Inhibition of the 1045 carbon steel corrosion by methionine and proline in PCMs solution have been investigated. Electrochemical measurements show that these inhibitors can protect steel against corrosion, with a maximal protection efficiency up to 95.0% by methionine/proline compound inhibitor at molar ratio equal to 5:3. All inhibitors act as anodic-type inhibitor. FESEM, EDS, XRD characterization indicates that the corrosion of steel starts from pitting corrosion of Cl−ion, and gradually evolves into a general corrosion. The NH4FePO4·nH2O, Fe2O3 are the main corrosion products. XPS study confirms that Met and Pro molecule can adsorb on steel surface and form inhibition films. The inhibition mechanism was further investigated through theoretical modeling studies.

Publications

- Zhang, W., Henschel, T., Söderlind, U., Khanh-Quang Tran and Xu Han; ***"Evaluation of various biomass feedstocks by using thermogravimetric and online gas analysis"***, Energy Procedia, in press, (2016)
- Zhang, Zhe, Ningchen Tian, Wennan Zhang, Xiaodong Huang, Le Ruan and Ling Wu, ***"Inhibition of carbon steel corrosion in phase-change-materialssolution by methionine and proline***", Corrosion Science 111, 675–689 (2016)

Jiayi Yang, PhD Student



Cellulose based composites from aqueous solvents

Research results 2016

The need for society to replace oil-based fuels and materials with products derived from renewable resources is growing along with reports on increasing carbon dioxide content in the atmosphere, causing climate change. Among the most abundant renewable biomaterials, suitable for this purpose, are cellulose from wood and chitosan derived by degradation of chitin from the exoskeleton of crustaceans. Both biopolymers have β-glucosidic bonds and very similar structure. Their somewhat unique properties; especially the strong mechanical strength, biocompatibility and thermal stability of cellulose,[1-2] and the wound healing, antibacterial properties of chitosan, as well as their ability of self-assembly into intriguing micro- or nano-sized structures, provide many options and ideas for functional materials design[3-4].

In year 2016, both cellulose and chitosan dissolution were successfully prepared in environmental benign aqueous solvents. The dissolve polymer solutions were stable at room temperature and were mixed to make composites with different functionalities. Cellulose based composite spheres were prepared in a tunable size range. Cellulose based composite films were also prepared as for a potential substituent in plastic packaging materials.

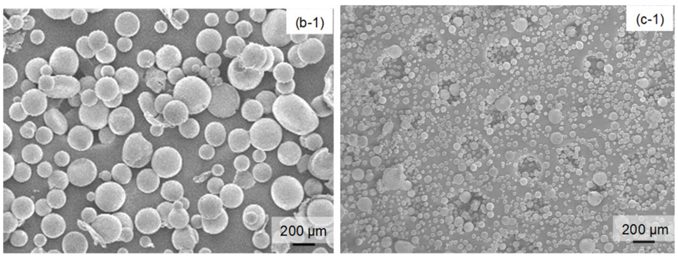


Figure 1. Cellulose based spheres with different size distribution

Figure 2. Cellulose based biocomposite film

References

1. Nishio, Y., Hyperfine composites of cellulose with sythetic polymers. In *Cellulosic Polymers, Blends and Composites*, Gilbert, R. D., Ed. Hanser Publishers: Munich, 1994; p 157.
2. Yamashiki, T.; Kamide, K.; Okajima, K., New cellulose fiber from aqueous alkali cellulose solution. In *Cellulose sources and exploitation: industrial utilization, biotechnology and physico-chemical properties*, Kennedy, J. F.; Phillips, G. O.; Williams, P. A., Eds. Ellis Horwood: Chichester, 1990; p 197.
3. Jain, D.; Banerjee, R., Comparison of ciprofloxacin hydrochloride-loaded protein, lipid, and chitosan nanoparticles for drug delivery. *J. Biomed. Mater. Res., Part B* **2008,** *86B* (1), 105-112.
4. Burkatovskaya, M.; Tegos, G. P.; Swietlik, E.; Demidova, T. N.; P. Castano, A. P.; Hamblin, M. R., Use of chitosan bandage to prevent fatal infections developing from highly contaminated wounds in mice. *Biomaterials* **2006,** *27* (22), 4157-4164.

Dr. Gunilla Pettersson

Development of CTMP & TMP Technologies

Research results 2016

During 2016 I have been involved in several research projects in the area of high yield pulping technology.

The project **"Advanced HYP for paperboard"** started in April 2015 in cooperation with SCA Östrand, Stora Enso and Valmet. Here the project goal is to develop and demonstrate techniques, based on hardwood (CTMP) particularly birch, to be used in manufacturing of paperboard. The total energy consumption in refining of such hardwood CTMP should be lower than 700 kWh/ton, to be compared to about 1200 kWh/ton in standard CTMP manufacturing. At present a main obstacle to use birch CTMP in some paperboard qualities, e.g. liquid board, is a too high content of extractives. These can cause problems with smell and taste from the packaging material or, in the worst case, from the packed products. Improved techniques have to be developed to make birch CTMP an attractive complement to spruce CTMP for the paperboard industry. Recently, two different full scale test-trial at SCA Östrand were performed, where HT-CTMP (high-temperature) from birch was manufactured, in combination with suitable refiner segments and different refiner line settings it was possible to achieve an energy reduction by up to 30% by two different set-ups. Analyses of extractives from different positions in the mill were examined. A pilot plant trial at Valmet has also been carried out together with Valmet and Stora Enso Research, where LC-grinding on different birch pulps were studied.

In the project **"Refining of softened TMP fibers"** we are developing non-conventional refiner segment patterns in cooperation with Valmet. The objective is to make it possible to refine high yield pulp fibers which have been softened (by high temperature or by the use of chemicals) under stable conditions. In conventional refining, using standard segments, there are often problems when refining a softened wood material since the refiner gap needs to be very small and the process therefore gets extremely sensitive for any disturbances. With the new segments, fibers can be treated energy efficiently in a wider plate gap which also make it possible to use earlier suggested methods to reduce energy consumption in mechanical pulping. The segment evaluation trials have been carried out in pilot plant scale and a mill scale trial has been performed in autumn 2016 with good results.

In a project founded by Åforsk, Troedsson and Swedish Energy Agency I have been working with **"Strong paper from CTMP".** This study was carried out on sheets from spruce CTMP fibers, which are surface treated with a mix of cationic starch and CMC and blended with 20% bleach softwood chemical pulp fibers before handsheets were prepared in a Rapid Köthen sheet former, where the sheets were dried to 40-55% d.c. The sheets were pressed in a hot press nip in a pilot machine with adjustable pressure and heat. Both low and high nip pressure were used in combination with two different nip temperatures, 80°C and 100°C, to achieve sheets in a broad range of densities. The results show that remarkable improvements are possible, both in terms of tensile index (up to 85 kNm/kg), see figure 1, and compression strength, SCT, (up to 38 kNm/kg) on the CTMP-based sheets under optimal conditions at papermaking, i.e. consolidate the sheet structure in a press nip at evaluated temperatures.

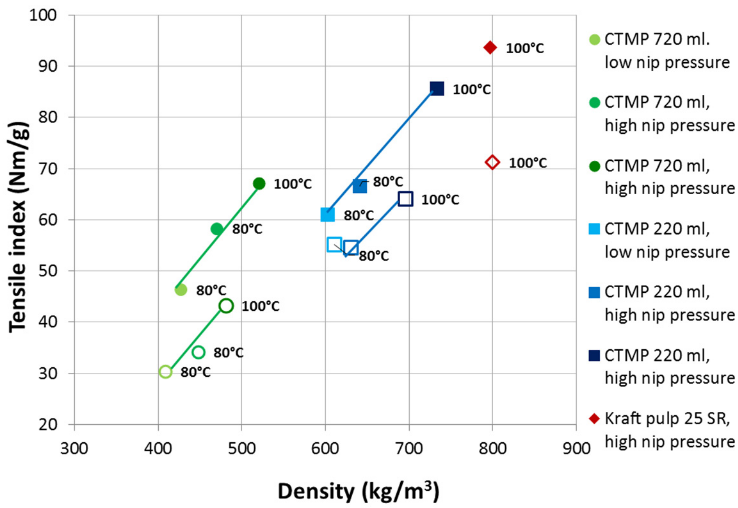


Fig 1. *Tensile index values of sheets made from two different CTMP pulps (CSF 720 ml and 220 ml) blended with kraft pulp at 80/20 mixtures. The fibers in the*

sheets were either untreated (unfilled icons) or treated with starch/CMC (filled icons). Effects of a low and a high nip pressure at two different temperatures are shown.

Publications

- Pettersson G. , Norgren S. , Höglund H. and Engstrand P. (2016) ***Low Energy CTMP in Strong and Bulky Paperboard Plies***, Tappi Papercon-May 15-18, 2016 Cincinnati, USA
- Marais A. , Enarsson L-E. , Pettersson G. , Lindström T. and Wågberg L. (2016) ***Pilot-scale papermaking using Layer-by-Layer treated fibres; comparison between the effects of beating and of sequential addition of polymeric additives***, Nordic Pulp & Paper Research Journal, vol. 31: 2, pp. 308-314.
- Osong S. H. , Norgren S. , Pettersson G. , Engstrand P. , Còrdova A. , Afewerki S. and Alimohammadzadeh R. (2016). ***Processing of nanocellulose and applications relating to CTMP-based paperboard and foams***. I International Mechanical Pulping Conference 2016, IMPC 2016. S. 87--93.
- Pettersson G. , Norgren S. and Höglund H. (2016). ***Strong paper from spruce CTMP***. I International Mechanical Pulping Conference 2016, IMPC Jacksonville, USA. S. 229--233.

Amanda Mattsson,
PhD student

Light-weight Structural Composites from Fibre-based Materials

Research results

My research project focuses on developing light-weight structural composites from fibre-based materials. In this regard, we have developed a probabilistic design model that characterizes the material behavior under realistic loading conditions (i.e., its "true performance"). The two new material parameters that we found, durability and reliability, play an important role for the performance of material.

We have preformed Monte Carlo simulations of a fibre network in order to understand how fibre properties and network structures affect durability and reliability. The results were presented at an international conference (ECCOMAS 2016) and later submitted to Physical Review E. Additionally, we have developed a new loading-rate-controlled compression test method to determine these parameters.

Figure 1 shows benchmarking results for containerboard with other materials used for advanced fibre composites. The cellulose-based fibre networks are favorably compared with other materials with balanced reliability and durability.

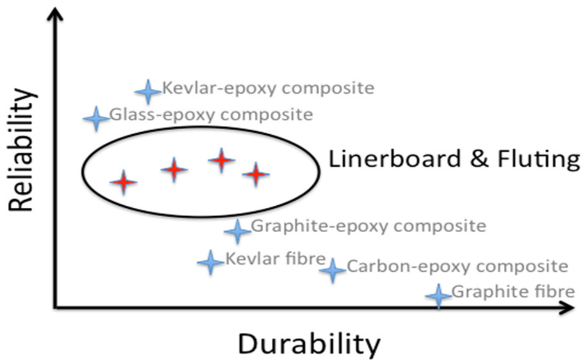


Fig 1. Benchmarking of container board, linerboard and fluting, in comparison with more advanced fibres and fibre composites.

Achievements of the year

Presentations

International conference

Mattsson, A., and Uesaka, T., "Statistical failure of fibre network under creep condition", European Congress on Computational Methods in Applied Sciences and Engineering, Crete Island, Greece, 5-10 June, 2016.

National conference

Mattsson, Amanda, "Lightweight Structural Composites from Fibre-based materials", Ekmandagarna, Stockholm, Sweden, Jan., 2016.

Public reach

Mattsson, Amanda, "Quantum Paper – Designing Fibre and Network for Light-weight Composites", Science and Innovation Days, Sundsvall, Sweden, Oct., 2016.

Mattsson, Amanda, "Framtidens hållbara produkter kommer från skogen!", Vetenskapslunch Kulturmagasinet, Sundsvall, Sweden, Oct., 2016.

Mattsson, Amanda, "Lightweight Structural Composites from Fibre-based materials", SCA, R&D Centre, Sundsvall, Sweden, May, 2016.

Visits

Mattsson, Amanda, "Time-dependent, Stochastic Failure of Fibre-based Materials", University of New South Wales, Mechanical and Manufacturing Engineering Department, Sydney, Australia, Nov., 2016.

Mattsson, Amanda, "Time-dependent, Stochastic Failure of Fibre-based Materials", Monash University, Chemical Engineering Department, Melbourne, Australia, Nov., 2016.

Mattsson, Amanda, "Time-dependent, Stochastic Failure of Fibre-based Materials", Orora Fibre Packaging, Melbourne, Australia, Nov., 2016.

Awards

Best Pecha Kucha-presentation at Ekmandagarna for PhD Students, Stockholm, Sweden, Jan., 2016

Viviane Forsberg
PhD Student

Research results 2016

Last year was a great year in my academic career. I published two journal papers and had my licentiate seminar in September 2016. My field of research is liquid exfoliation of layered materials such as graphite and molybdenum disulfide for inkjet printing. The goal of our project is to deposit exfoliated materials into large surface areas such as paper. MoS2, the main layered material that I study, is a semiconductor and can be used for applications such as solar cells.

Figure 1 is an illustration of the exfoliation steps of the bulk MoS2 powder until the final printing result.

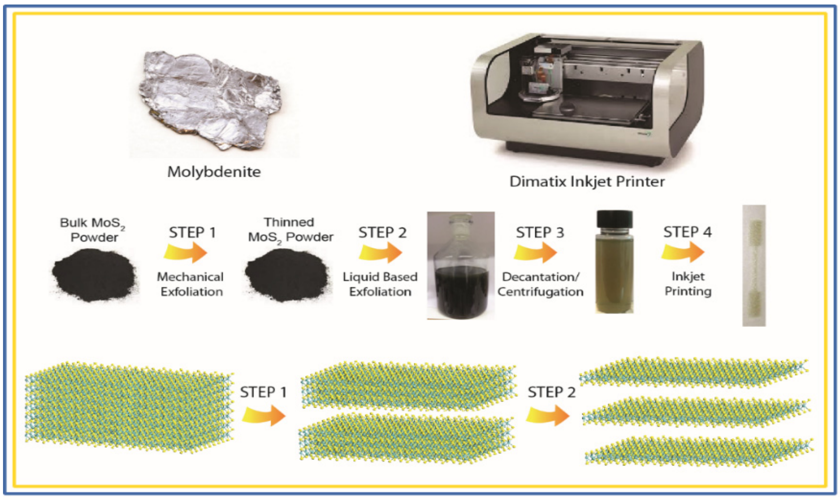


Figure 1: (Top) Molybdenite ore and Dimatix Inkjet Printer. (Middle) Exfoliation steps to print a MoS2 test pattern. (Bottom) Exfoliation steps in atomic scale.

Now after the licentiate exam I am continuing to tune the ink properties of the inkjet inks of layered materials in environmental friendly solvents tailoring the concentration, viscosity, particle size and stability. I aim to achieve stable inks to print electrodes for supercapacitors using not only inkjet printing but also flexography and paper coating.

I received stipendium from Grafiska Företagen for three consecutive years (2014, 2015 and 2016) to participate in conferences in USA, U.A.E. (Dubai), Manchester and China. The total of the stipendium was 90.000 SEK.

In 2010 I received the Palm Award as the best Master Student in the Pulp and Paper Master Program at the Munich University of Applied Sciences in Germany.

In 2003 I received a stipendium from the Rotary Foundation to study at the Technical University of Denmark for one academic year. I also studied at the Copenhagen Business School during the summer.

Publications

- Forsberg, Viviane. ***Liquid Exfoliation of Molybdenum Disulfide for Inkjet Printing***. 2016. Licentiate thesis. Mid Sweden University. ISBN: 978-91-88025-71-5
- Forsberg, V., Zhang, R., Bäckström, J., Dahlström, C., Andres, B., Norgren, M., Andersson, M., Hummelgård, M. and Olin, H., ***Exfoliated MoS2 in water without additives***. PLoS One, 11 (4), 2016.
- Forsberg, V., Zhang, R., Andersson, H., Bäckström, J., Dahlström, C., Norgren, M., Andres, B., Olin, H. ***Liquid exfoliation of layered materials in water for inkjet printing.*** Journal of Imaging and Science Technology, 60 (4), 2016.
- Zhang, R., Forsberg, V., Hummelgård, M., Andres, B., Forsberg, S., Andersson, M., Olin, H. ***Thermally reduced kaolin-graphene oxide nanocomposites for gas sensing.*** Scientific Reports, 5, 2015.
- Forsberg, V., Andres, B., Zhang, R., Hummelgård, M., Forsberg, S., Shimizu, K., Olin, H. ***Exfoliated MoS2 for paper based supercapacitors and photodetectors***. ICFPE, 5th International Conference on Flexible and Printed Electronics, 2014, 437-438.
- Forsberg, V., Zhang, R., Hummelgård, M., Andres, B., Dahlström, C., Norgren, M., Andersson, M., Olin, H. ***Exfoliated Layered Materials for Digital Fabrication.*** 31st NIP - International Conference on Digital Printing Technologies and Digital Fabrication, 2015, 192-194.

Dr. Italo Sanhueza

Research results 2016

During the Fall of 2016, I joined Mid Sweden University and the group of Organic Chemistry, Prof. Cordova, in the Department of Natural Science (NAT). Previously I was part of Prof. Schoenebeck's group at ETH Zurich as a PhD Student in physical organic chemistry. I defended my doctoral thesis at ETH Zurich in November 2016 with the title "Unravelling chemical mysteries of key steps in Pd-catalyzed reactions and related transformations – Computations & Experiments".

I am very happy to be here in Sundsvall and I look forward to work together with the talented staff and researchers of Mid Sweden University.

Research

My research in the Organic Chemistry group focuses on finding innovative green catalytic approaches to valorize biomass, such as Lignin and Cellulose into high value products (e.g. biofuel, bio-chemicals and biomaterials). Here follows a short summary of the projects I am involved in.

Green catalytic valorization of Lignin: Project 1

Lignin is a very interesting macromolecule that is highly abundant in nature. In fact, approximately 15-30% of the tree consists of Lignin. However, while Lignin is highly abundant, in industry, Lignin has mainly been considered a waste product: used to generate electricity and heat. In the past years the Cordova group has shown that by using green catalytic chemistry it is possible to efficiently transform lignin into high value products. We are now investigating this process further in collaboration with academic and industrial partners.

Green catalytic formation and design of nanocellulose: Project 2

Nanocellulose has risen as a very interesting resource to create a range of products that can allow our society to go from a petroleum based society to a bioeconomy. In addition, nanocellulose has very interesting economic-industrial properties as it has the potential to be employed in a range of high value products in life science, to advanced papers and cardboards as well as in water purification. The formation of nanocellulose has however not been economically feasible and many occasions, both the formation as well as modification of nanocellulose has used chemical processes which are not green (e.g. using chlorine based oxidants, radical initiators and high energy). Here in the Cordova group we aim to address these issues using green catalytic chemistry to (1) form nanocellulose and (2) design nanocellulose with a range of interesting properties. This will be done in collaboration with academic and industrial partners.

Publications

- T. Sperger, I. A. Sanhueza, F. Schoenebeck, **Computation & Experiment – A Powerful Combination to Understand and Predict Reactivities**, *Acc. Chem. Res.* **2016**, *49*, 1311.

Per Engstrand, Professor

Research focus

My research approach is to find ways to help the Swedish Forest Industry to widen the perspectives with regard to what products that can be produced from forest fibers and also how to produce present and new products in an ecofriendly, sustainable and also feasible way. This means that I focus on energy efficient high yield pulping systems combined with efficient papermaking. Within the research profile e2mp (energy efficient mechanical pulping) we have found that a Process Intensification (PI) approach can be quite useful also in pulp and papermaking systems. To succeed in PI you have to understand the fundamental of both the wood material and the process systems. Within the latest 5-year period we have together with our industrial partners and academic partners shown in full scale how to reduce electric energy demand by 25% (compared to best available technology). Furthermore, we have through tests in small pilot scale utilizing fundamental knowledge of high yield fiber properties been able to produce very strong materials from pulps produced at very low energy demand.

As there are also many opportunities to improve pulp and paper technologies by extracting side-streams that could be better utilized for other purposes as different types of nanocellulose, green chemicals for several different purposes and even biofuels this is also a part of my research. The research work along the chain from forest via pulp, paper and side-stream unit operation has led ideas as both Forest as a resource we at present run mainly within FORIC (Forest as a resource industrial research college). FORIC is financed by the Knowledge Foundation and a part of our research environment Transformative Technologies at Mid Sweden University.

FORIC is a graduate school in close cooperation with companies in Sweden where graduate students will increase their competitiveness. Academia and industry will benefit from interacting with each other.

Today biorefineries become an important way to refine forest resources and develop the industry in a sustainable direction. But not even the really big companies can handle all the processes around the technology used in a biorefinery themselves. Optimizing the chain from forest to finished product therefore requires collaboration between different companies in the forest industry and also other companies close to forest industries, such as logistics, recycling, waste, energy etc.

Publications

- Engstrand, P., ***Energy efficient mechanical pulping – summary of the Scandinavian industry initiative research work 2011 - 2015*** In *IMPC 2016, September 28-30, Jacksonville, Florida, USA*.
- Engstrand, P. , Gradin, P. , Hellström, L. , Carlberg, T. , Sandström, P. , Liden, J. , Söderberg, M. & Mats, E. (2016). ***Improved refining energy efficiency in thermo-mechanical pulping by means of collimated wood chipping – from solid mechanics to full scale evaluation***. In *PaperWeek Canada 2016 Conference February 1 to 5, 2016, Montreal: Technical Track Program*.
- Engstrand, P. (2016). ***Energy efficient mechanical pulping – summary of the Scandinavian industry initiative research work 2011 - 2015.*** In *2016 International Mechanical Pulping Conference, Jacksonville, Florida, USA September 28-30, 2016: SESSION 11: INDUSTRY INITIATIVE FOR ENERGY REDUCTION*. Georgia 30092 USA: pp. 288--303.
- Osong, S. H. , Norgren, S. , Pettersson, G. , Engstrand, P. , Còrdova, A. , Afewerki, S. & Alimohammadzadeh, R. (2016***). Processing of nanocellulose and applications relating to CTMP-based paperboard and foams.*** In *International Mechanical Pulping Conference 2016, IMPC 2016*. pp. 87--93.
- Osong, S. H. , Dahlström, C. , Forsberg, S. , Andres, B. , Engstrand, P. , Norgren, S. & Engström, A. (2016). ***Nanofibrillated cellulose/nanographite composite films.*** *Cellulose (London),* vol. 23: 4, ss. 2487-2500.
- Osong, S. H. , Norgren, S. , Engstrand, P. , Lundberg, M. , Reza, M. & Tapani, V. (2016). ***Qualitative evaluation of microfibrillated cellulose usingthe crill method and some aspects of microscopy***. *Cellulose (London),* vol. 23: 6, ss. 3611-3624.
- Osong, S. H. , Norgren, S. & Engstrand, P. (2016). ***Processing of wood-based microfibrillated cellulose and nanofibrillated***

cellulose, and applications relating to papermaking: a review. *Cellulose (London)*, vol. 23: 1, ss. 93-123.

- Sandberg, C. , Engstrand, P. & Berg, J. (2016**). *System Aspects on Low Consistency Refining of Mechanical Pulp.*** In *TAPPI 2016 International Mechanical Pulping Conference (IMPC)*. pp. 485--495.
- Nelsson, E. , Sandberg, C. , Svensson-Rundlöf, E. , Paulsson, M. , Granfeldt, T. , Engberg, B. & Engstrand, P. (2016**). *Mill scale production of TMP with double disk refining-The effects of a mild sulfonation, atmospheric preheating and refining temperatures***. In *International Mechanical Pulping Conference 2016, IMPC 2016*. pp. 249--259.
- Karlström, A. & Engstrand, P. (2016). ***Refining efficiency for future CTIVIP and TMP systems co-optimizing fundamental wood material knowledge with a soft sensor control approach.*** In *International Mechanical Pulping Conference 2016, IMPC 2016*. pp. 304--316.
- Pettersson, G. , Norgren, S. , Höglund, H. & Engstrand, P. (2016). ***Low energy CTMP in strong and bulky paperboard plies.*** In *Paper Conference and Trade Show, PaperCon 2016*.pp. 556--564.

Patents

Method for producing and processing wood chips Engstrand, P. , Gradin, P. , Gregersen, Ø., Hellström, L. , Carlberg, T.,
WO 2011108967 A1

要約書 英語で利用可能

明細書 英語で利用可能

特許請求の範囲 英語で利用可能

Citation indices	All	Since 2012
Citations	359	197
h-index	10	8
i10-index	10	5

Magnus Norgren, Professor

My research interest covers the area of surface and colloid chemistry; materials and phenomena. Specifically I focus on wood polymers and related conventional and novel processes convert them to nanocomposites and functional materials. I am also interested in special surfactants with additional features like metal chelation.

I am the group leader of Surface and Colloid Engineering and hold a PhD in physical chemistry from Lund University, with Prof Björn Lindman as main supervisor.

Publications

- Eivazihollagh, A. , Bäckström, J. , Dahlström, C. , Carlsson, F. , Ibrahem, I. , Lindman, B. , Edlund, H. & Norgren, M. (2017). ***One-pot synthesis of cellulose-templated copper nanoparticles with antibacterial properties***. *Materials letters (General ed.),* vol. 187, ss. 170-172.
- Yang, J. , Duan, J. , Zhang, L. , Lindman, B. , Edlund, H. & Norgren, M. (2016). ***Spherical nanocomposite particles prepared from mixed cellulose–chitosan solutions***. *Cellulose (London),* vol. 23: 5, ss. 3105-3115.
- Forsberg, V. , Zhang, R. , Joakim, B. , Dahlström, C. , Andres, B. , Norgren, M. , Andersson, M. , Hummelgård, M. & et al. (2016). ***Exfoliated MoS2 in Water without Additives.*** *PLoS ONE,* vol. 11: 4
- Forsberg, V. , Zhang, R. , Andersson, H. , Bäckström, J. , Dahlström, C. , Norgren, M. , Andres, B. & Olin, H. (2016). ***Liquid Exfoliation of Layered Materials in Water for Inkjet Printing***. *Journal of Imaging Science and Technology,* vol. 60: 4, ss. 40405-1-40405-7.
- Svanedal, I. , Andersson, F. , Hedenström, E. , Norgren, M. , Edlund, H. , Satija, S. K. , Lindman, B. & Rennie, A. R. (2016). ***Molecular Organization of an Adsorbed Layer*** : A Zwitterionic, pH-Sensitive

Surfactant at the Air/Water Interface. *Langmuir,* vol. 32: 42, ss. 10936-10945.

- Duan, R. , Westerlind, B. , Norgren, M. , Anugwom, I. , Virtanen, P. & Mikkola, J. (2016). ***Fibre stress-strain response of high temperature chemi-thermomechanical pulp treated with switchable ionic liquids.*** *BioResources,* vol. 11: 4, ss. 8570-8588.

Björn Lindman, Guest Professor

Publications

- Alves, L. , Medronho, B. , Antunes, F. E. , Topgaard, D. & Lindman, B. (2016). ***Dissolution state of cellulose in aqueous systems. 1. Alkaline solvents.*** *Cellulose (London),* vol. 23: 1, pp. 247-258.
- Yang, J. , Duan, J. , Zhang, L. , Lindman, B. , Edlund, H. & Norgren, M. (2016). ***Spherical nanocomposite particles prepared from mixed cellulose–chitosan solutions.*** *Cellulose (London),* vol. 23: 5, pp. 3105-3115.
- Svanedal, I. , Andersson, F. , Hedenström, E. , Norgren, M. , Edlund, H. , Satija, S. K. , Lindman, B. & Rennie, A. R. (2016). ***Molecular Organization of an Adsorbed Layer*** : A Zwitterionic, pH-Sensitive Surfactant at the Air/Water Interface. *Langmuir,* vol. 32: 42, pp. 10936-10945.
- Alves, L. , Medronho, B. , Antunes, F. E. , Topgaard, D. & Lindman, B. (2016). ***Dissolution state of cellulose in aqueous systems. 2. Acidic solvents.*** *Carbohydrate Polymers,* vol. 151, pp. 707-715.
- Lindman, B. , Medronho, B. & Theliander, H. (2015). ***Editorial*** : Cellulose dissolution and regeneration: systems and interactions. *Nordic Pulp & Paper Research Journal,* vol. 30: 1, pp. 2-3.
- Lindman, B. , Medronho, B. & Karlström, G. (2016). ***Clouding of nonionic surfactants.*** *Current Opinion in Colloid & Interface Science,* vol. 22, pp. 23-29.

Armando Córdova, Professor

Research area of interest

- Development and application of hetero-geneous catalysts (metal and organic) and metal-free catalysis
- New multi-catalytic method strategies for converting biomass to valuable products and materials
- Valorization of biomasses such as lignin
- Eco-friendly surface modification of lingo-cellulose (e.g. cellulose, various pulps, nanocelluloses and different types of lignocellulosic fibers)

Publications

- Palo-Nieto, C. , Afewerki, S. , Anderson, M. , Tai, C. , Berglund, P. & Cordova, A. (2016). ***Integrated Heterogeneous Metal/Enzymatic Multiple Relay Catalysis for Eco-Friendly and Asymmetric Synthesis***. *ACS Catalysis,* vol. 6: 6, pp. 3932-3940.
- Afewerki, S. & Cordova, A. (2016). ***Combinations of Aminocatalysts and Metal Catalysts*** : A Powerful Cooperative Approach in Selective Organic Synthesis. *Chemical Reviews,* vol. 116: 22, pp. 13512-13570.
- Osong, S. H. , Norgren, S. , Pettersson, G. , Engstrand, P. , Còrdova, A. , Afewerki, S. & Alimohammadzadeh, R. (2016). ***Processing of nanocellulose and applications relating to CTMP-based paperboard and foams.*** In *International Mechanical Pulping Conference 2016, IMPC 2016*.. pp. 87--93.

Tetsu Uesaka, Professor

Research results and reflection in 2016

At the beginning of 2016, I had an opportunity to contribute an article to Nordic Pulp and Paper Research Journal, entitled "Complex matters: Things that matter". The article is based on my speech at the joint conference of paper physics and paper chemistry, which was held in the fall of 2015 in Tokyo. The topic is about "Complex Systems".

Complexity is an emerging field of scientific research. It includes a large class of problems in science, engineering, and even society. One example is a stock market. It is known that stock price moves up and down because of underlying economic conditions, speculation, bubbles, panics and fears, government policy, and also, these days, computer programs run by large financial institutions. It is of great interest for investors, business owners and policy makers to understand and even to predict (if possible) this complex behavior. Why is it so "complex"? Because there are an enormous number of different *components* (players) involved. They are interacting each other, and interactions are nonlinear. The process is dynamic and often adaptive (history-dependent). Of course, such system is not unique to stock markets, but we find numerous examples in biological systems (e.g., human brain, immune system, and ecosystem), engineering structures (e.g., electric power grids and control loops in large manufacturing plant), and materials (colloids, suspensions, fibre networks, and granular systems), which are of our prime interest.

Why are we interested? Are we making things more complicated than simpler? Actually not! Many of the design problems of materials and products are, unfortunately, the problem of complex systems.

Take an example of strength of materials. It is known, from the days of Leonardo da Vinci, that strength properties are *size-dependent*: the larger size, the lower the strength. Size-dependence, or scaling of strength properties, has been investigated for many years at many fronts (engineering, materials science, and statistical mechanics). The prevailing view is that material failure is controlled by the weakest spot in the system and the resulted strength distribution follows Weibull distribution. However, the recent studies of complex system failure showed that actual material failure is far more complex than the above simple picture. The weakest spot doesn't control the failure of entire system. Material failure resembles much more to phase tansition, a self-organised event of evolving damages. Our project on light-weight composites (PhD student: A. Mattsson) found that lifetime, another measure of long-term strength, actually follows a novel distribution (a double-exponential form) in a wide-range of scale, instead of Weibull distribution. The implication of this research is far-reaching. We have realised that the current and also potential constructions of light-weight structures using fibre networks are very favourable for enhancing reliability of long-term performance. This project is now moving into a new stage of light-weight composite design.

Fibre network is one of the main material systems which our complex materials group is working on. In complexity science, network is one of the highlighted areas, because its wide-spread applications, for example, biological networks, neural networks, traffic networks, world-wide-web, and social networks. Many fibre networks, in our context, have random construction: fibres are not orderly placed in a space both in the position and orientation, but placed more or less randomly. (The situation is similar to polymer networks in a different length scale.) The implication of this random nature of the structure is recently investigated in our project on fibre network for hygiene products (Postdoctoral fellow: S. Hossain, and PhD student: Per Bergström). The question is what constitutes *softness* of tissues, towels, and diapers when one touches the surface of such products. Does this have to do with how individual fibres deform, such as bending and twisting? To our big surprise, it is non-uniform deformation of the fibre network (called non-affine deformation) that creates very soft response. Simply put, fibre deformation in the network is highly "undemocratic": only a very small portion of fibres are deformed and stressed, but an overwhelming majority just moves without being stressed. Therefore, what matters to softness is not individual fibres' deformation characteristics, but the non-uniform structure of fibre network itself. The latter is, to a greater extent, controlled by certain geometries of fibres. This information is critical in selecting and designing fibres for hygiene products and also for generating non-woven structures in the manufacturing process.

An ultimate complex system is human body! Our new project on skin mechanic (PhD student: S. Sarangi) is focusing on unveiling the mechanism of pressure ulcer, a silent epidemic of today's ageing society in many developed countries. Skin care and skin health are an important area where hygiene products can play a positive role. We are currently developing a new computer code based on particle methods to analyse stress distributions within a human body, which is modelled as a system of skin, fat, muscle layers, as well as bone structures. We are looking forward to see how this complex puzzle is solved.

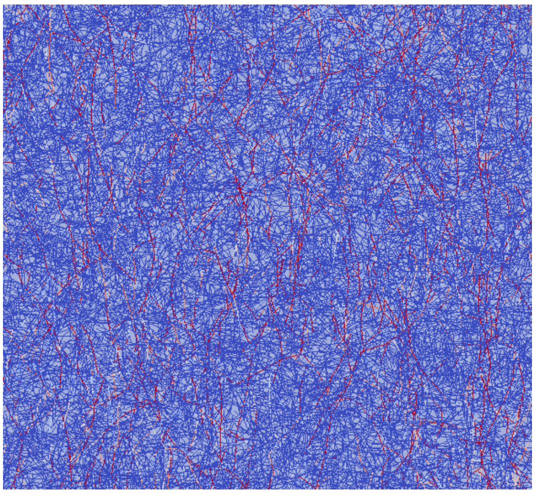


Figure 1 Strain energy map of individual fibres showing "undemocratic" nature of fibre deformation in fibre network. Red-coloured fibres indicate highly stressed fibres.

Publications

- Uesaka, Tetsu**. "*Complex Matters: Things that matter.*"** *Nordic Pulp & Paper Research Journal* 31.2 (2016): 213-218.
- Alimadadi, Majid, and Tetsu Uesaka. "***3D-oriented fiber networks made by foam forming.***" *Cellulose* 23.1 (2016): 661-671.

Håkan Olin, professor

KM2 – Innovative Green Energy

The KM2 objective is to develop innovations in green energy; harvest, store and use energy. Our applications include wind energy, supercapacitors, batteries, paper solar cells, batteries, displays, street lights and a materials and innovations laboratory.

The need for green energy is approx. 100 squaremetres per capita and year globally. The problem is high cost production of energy devices and small production capacity. Compare to paper industry production with low cost, 0.1 €/squaremeters and large production capacity, today 500 squaremeters/capita. The KM2 vision is to combine green nanomaterials with paper industry methods to produce green innovative energy.

There are good opportunities for the region's businesses to develop new products for new purposes by combining materials with paper industry production processes. The paper industry has the production capacity and the skills for rapid and cost-effective production of large areas of renewable and recyclable raw material.

The project KM2 is based on the regional company need of knowledge in materials engineering and analytical and pilot equipment to develop innovations in green energy. The project consists of six sub-projects. KM2 also include an upgrade of the existing material laboratory at Mid Sweden University and production of a test environment that includes green street lights for Nordic conditions.

LEAP – Large-Area Energy Application Platform

By utilizing novel materials and processing combinations, we aim at demonstrating low-cost and large-scale production methods for thermoelectric generators which will contribute to the vision of a large-area, low cost electronics platform for energy applications. The importance of this is reflected in the two and three-digit growth rates of green energy markets.

The vision of this synergy project is a large-area electronic platform suitable for low-cost production of energy components. The LEAP synergy project provide a contribution towards this vision by addressing the following core question: Which materials-processing combination will allow low-cost, large-area production of thermoelectric generators?

Three projects contribute to answer this core question:

1) Glass-on-paper
2) Printed Conductor
3) Thermoelectric Generator

Publications

- Forsberg, V. , Zhang, R. , Joakim, B. , Dahlström, C. , Andres, B. , Norgren, M. , Andersson, M. , Hummelgård, M. & et al. (2016). ***Exfoliated MoS2 in Water without Additives.*** *PLoS ONE,* vol. 11: 4
- Forsberg, V. , Zhang, R. , Andersson, H. , Bäckström, J. , Dahlström, C. , Norgren, M. , Andres, B. & Olin, H. (2016). ***Liquid Exfoliation of Layered Materials in Water for Inkjet Printing.*** *Journal of Imaging Science and Technology,* vol. 60: 4, ss. 40405-1-40405-7.
- Andres, B. , Engström, A. , Blomquist, N. , Forsberg, S. , Dahlström, C. & Olin, H. (2016). ***Electrode Mass Balancing as an Inexpensive and Simple Method to Increase the Capacitance of Electric Double-Layer Capacitors.*** *PLoS ONE,* vol. 11: 9, ss. 1-12.
- Edvardsson, S. , Karlsson, K. & Olin, H. (2016). ***corr3p_tr*** : A particle approach for the general three-body problem. *Computer Physics Communications,* vol. 200, ss. 259-273.
- Blomquist, N. , Engström, A. , Hummelgård, M. , Andres, B. , Forsberg, S. & Olin, H. (2016). ***Large-Scale Production of Nanographite by Tube-Shear Exfoliation in Water.*** *PLoS ONE,* vol. 11: 4
- Volpati, D. , Mårtensson, N. , Anttu, N. , Viklund, P. , Sundvall, C. , Åberg, I. , Bäckström, J. , Olin, H. & et al. (2016). ***Spectroscopic investigations of arrays containing vertically and horizontally aligned silicon nanowires.*** *Materials Research Express,* vol. 3: 12
- Abdipour, M. , Lorentzen, L. & Olin, H. (2016). ***A Design Research Lab—An Integrated Model to Identify Conscious and Unconscious Behavior in the Design Process***. I *Advances in Intelligent Systems and Computing : Design for Inclusion*. (Advances in Intelligent Systems and Computing). S. 553--563.

- Balliu, E. , Andersson, H. , Engholm, M. , Forsberg, S. & Olin, H. (2016). ***Laser-assisted reduction of graphene oxide for paper based large area flexible electronics.*** I *Proceedings of SPIE - The International Society for Optical Engineering*.

Håkan Edlund, professor

Publications

- Yang, J. , Duan, J. , Zhang, L. , Lindman, B. , Edlund, H. & Norgren, M. (2016). ***Spherical nanocomposite particles prepared from mixed cellulose–chitosan solutions.*** *Cellulose (London)*, vol. 23: 5, ss. 3105-3115.
- Svanedal, I. , Andersson, F. , Hedenström, E. , Norgren, M. , Edlund, H. , Satija, S. K. , Lindman, B. & Rennie, A. R. (2016). ***Molecular Organization of an Adsorbed Layer :*** A Zwitterionic, pH-Sensitive Surfactant at the Air/Water Interface. *Langmuir,* vol. 32: 42, ss. 10936-10945.
- Eivazihollagh, A., Bäckström, J., Norgren, M., Edlund, H.; ***Influences of the Operational Variables on Electrochemical Treatment of Chelated Cu(II)- in Alkaline Solutions Using a Membrane Cell***. *Journal of Chemical Technology & Biotechnology.* **2016**, 23XX

Erik Hedenström, Professor

Green Pro - Green chemicals from forest and forest waste products

In 2016 we started the research project Green Pro with the overall objective to develop and strengthen the region and its forest based industry via research aimed at new products and processes. The project reinforces the research environment in the biorefinery area at FSCN and Mid Sweden University which increases the possibility to cooperate with regional stakeholders to meet the growing interest in the biorefinary field. The following companies participates in the project: SEKAB Biofuels and Chemicals AB, SP Processum AB, Domsjö Fabriker AB, Labservice AB, Sylvestris AB, Colabitoil Sweden AB and Tärnsjö Garveri AB.

Our overall idea of the project is to develop biochemical processes where we use biomass as feedstock which selectively is transformed to value-added products using different types of fungi as bio-catalysts. The project focus is to study bio-catalysed degradation of lignin and a scientific challenge is to selectively degrade only the lignin in the biomass in order to produce fatty acids and lipids tailored for production of our primary target products, the next generation of fish feed and HVO-biodiesel. Screening of fungi species, reaction conditions, various biomasses etc are important project activities together with development of analytical methods which enables us to follow the bio-degradation in order to optimize the yield of the desired green chemical. Moreover, the project will focus on adapting the developed processes and products for industrial production.

Examples of some results expected from the project:

1. From forestry and paper industrial materials develop a biochemical process suitable for industrial scale production of the next generation of fish feed

2. From forestry and paper industrial materials develop a process suitable for industrial scale production of natural tanning agents

3. From forestry and paper industrial materials develop biochemical processes suitable for production of new products with biological activity for protection against pests, mold, bacteria and human diseases

4. From forestry and paper industrial materials develop a biochemical process suitable for industrial scale production of appropriate starting materials in the production of HVO-biodiesel

Publications

- Mitko, L. , Weber, M. G. , Ramirez, S. R. , Hedenström, E. , Wcislo, W. T. & Eltz, T. (2016). ***Olfactory specialization for perfume collection in male orchid bees.*** *Journal of Experimental Biology,* vol. 219: 10, ss. 1467-1475.
- Svanedal, I. , Andersson, F. , Hedenström, E. , Norgren, M. , Edlund, H. , Satija, S. K. , Lindman, B. & Rennie, A. R. (2016). ***Molecular Organization of an Adsorbed Layer :*** A Zwitterionic, pH-Sensitive Surfactant at the Air/Water Interface. *Langmuir,* vol. 32: 42, ss. 10936-10945.
- Zauli, A. , Carpaneto, G. M. , Chiari, S. , Mancini, E. , Nyabuga, F. N. , De Zan, L. R. , Romiti, F. , Sabbani, S. & et al. (2016***). Assessing the taxonomic status of Osmoderma cristinae (Coleoptera Scarabaeidae), endemic to Sicily, by genetic, morphological and pheromonal analyses.*** *Journal of Zoological Systematics and Evolutionary Research,* vol. 54: 3, ss. 206-214.
- Hedenström, E. , Fagerlund-Edfeldt, A. , Edman, M. & Jonsson, B. (2016). ***Resveratrol, piceatannol, and isorhapontigenin from Norway spruce (Picea abies) debarking wastewater as inhibitors on the growth of nine species of wood-decaying fungi.*** *Wood Science and Technology,* vol. 50: 3, ss. 617-629.

Rana Alimohammadzadeh
PhD Student

My research focuses on green chemistry and the development of new eco-friendly methods using organo- and heterogeneous metal catalysis. Here the overall aim is to find new innovative ways to valorize cellulose and lignin into high value products. One of my projects concern the surface modification of nanocellulose. Here I have successfully made the nanocellulose hydrophobic using organocatalysis. Encouraged by these results we are now designing a range of modified nanocellulose based materials using organocatalysis. This includes for instance making the material UV active, to give it antibacterial properties or to modify it as a support in heterogeneous catalysis.

The investigating of degradation of lignin with oxidation is also a project that I have worked on during the past year. The project aims involved synthesizing a variety of lignin model compound and studying the oxidation mechanism for these compounds in order to develop an efficient green chemical process that can convert the lignin into fuel and pharmaceutical products. In addition to this project I also work on the total synthesis of pharmaceutical compounds using heterogeneous metal catalysis. In this context, using heterogeneous metal catalyst can be considered ecofriendly since it allows recycling and prevents leaching, as well as, metal catalyst contaminations. Our aim is to make new innovative methods that are more efficient, more selective and greener, than what is currently known in literature.

Publications

- Osong, S. H. , Norgren, S. , Pettersson, G. , Engstrand, P. , Còrdova, A. , Afewerki, S. & Alimohammadzadeh, R. (2016). ***Processing of nanocellulose and applications relating to CTMP-based paperboard and foams.*** In *International Mechanical Pulping Conference 2016, IMPC 2016*.. pp. 87--93.

Christer Sandberg, Project leader

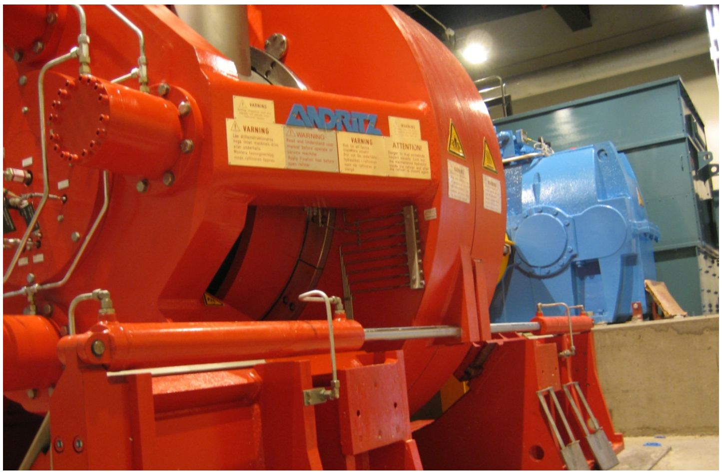
Low consistency refining system design for high yield pulping processes

Low consistency (LC) refining is used to improve energy efficiency and production capacity in mechanical pulping lines (TMP, GWD and CTMP). Full scale installations have though revealed some current limitations; the maximum specific refining energy that can be applied is quite low, which limits the energy saving potential and light scattering does not develop as much as in high consistency (HC) refining.

The purpose of the project is to evaluate systems with LC refining that contributes to overall low energy consumption and acceptable pulp properties. The goal is to:

- Evaluate systems with high intensity chip refining and second stage LC refining.
- Make it possible to apply 300 kWh/adt in LC refining and at this energy input increase tensile index by 20 Nm/g.

A combination of double disc (DD) and low consistency (LC next page) refining was shown to be a very efficient process that yields good pulp quality. Photo: Holmen



This will roughly correspond to a reduced refining energy of 300 kWh/adt compared to the most efficient processes today. The purpose of this project is to increase the specific energy in LC refining of TMP and increase the efficiency of the refining i.e. attain higher degree of fibre development at a certain SEC. The goal is to reduce refining energy with 300 kWh/adt compared to a BAT TMP line today.

Most of the work in this project is made with LC refiners installed in mills. The work is focused on two areas; 1) Improving the performance of LC refining itself and 2) Optimizing refining systems containing LC refiners.

This will be made by trying different approaches; chemical treatments that improve the refining efficiency and/or loadability. LC refining will also be combined with fibre fractionation to improve process performance. It is important to combine HC and LC refining in an optimal way, which will be evaluated in mill trials.

We have also initiated work aiming at implementation of Process Intensification principles for pulping processes.

Results 2016

Six process configurations containing high consistency (HC) and low consistency (LC) refiners were evaluated both in main line and reject line for production of pulp for printing papers in the Holmen Paper Braviken mill. HC-LC processes were compared with processes with only HC refining. Processes with two different types of chip refiners were studied –

single disc (SD) and double disc (DD). The purpose of that work was to evaluate energy efficiency and pulp quality for the processes.

LC refining was more energy efficient than HC refining for certain tensile index increase in all evaluated combinations. The highest energy efficiency was attained when LC refining was utilized in main line, but the difference was small compared to application on reject. The combination of DD chip refining and LC refining had the highest energy efficiency (tensile index at certain specific energy consumption) and produced pulp with somewhat lower fibre length but higher light scattering and lower shives content compared to a line with only SD HC refining. Thus, for printing papers it is beneficial to combine LC refining with high intensity HC chip refining. All processes with LC refining had somewhat lower light scattering and fibre length compared to the corresponding system with only HC refining.

The results were presented at the International Mechanical Pulping Conference 2016: **Sandberg, C., Berg, J.-E. and Engstrand, P,** (2016): *System Aspects on Low Consistency Refining of Mechanical Pulp,* Int. Mech. Pulping Conf. Proceedings, p. 485-495.

Two papers on Process Intensification for mechanical pulping have been submitted to NPPRJ.

Publications

- Sandberg, C., Berg, J.-E. and Engstrand, P, (2016): ***System Aspects on Low Consistency Refining of Mechanical Pulp,*** Int. Mech. Pulping Conf. Proceedings, p. 485-495.

Dr. Jan-Erik Berg

Improved energy efficiency in high yield pulping

To get some insight into the processes that are active during the refining of wood, the tangential force distribution in the plate gap is of interest. Over the years several designs of force sensors have been developed for this purpose. One drawback with these designs is that each sensor measures forces over quite a small area such that in order to cover the whole disc with a reasonably good resolution, many sensors have to be used. Also, there are problems to protect the active parts of the sensors from the harsh environment in the plate gap. In a paper that was published in 2016 a different concept is presented, in that the sensor is continuous and consists of a hollow radial bar equipped with strain gages on the inside. The instrumented bar is produced in two halves. Figure 1 shows the sensor before assembly. As can be seen from the figure, in total 16 strain gages in eight positions were used and the two halves were welded together using laser welding technique.

To put the force sensor to a test, it was inserted into an atmospheric single disc, 20-inch-diameter pilot refiner equipped with 5811B segments. The rotational speed was 600 rpm and the plate gap was 0.7 mm. The feed pulp (26.9% pulp consistency and 600 CSF) was produced in advance from Norway spruce. All trials were performed at Valmet pilot plant at Sundsvall, Sweden.

The trial showed that the sensor had a sufficient sensitivity and that it could sustain the loads appearing during refining without any malfunction. Figure 2 shows the time averages for the strains for all eight pairs of gages and for six different combinations of production rates and dilution flows. As expected, higher production rates and lower dilution flows result in higher strains.

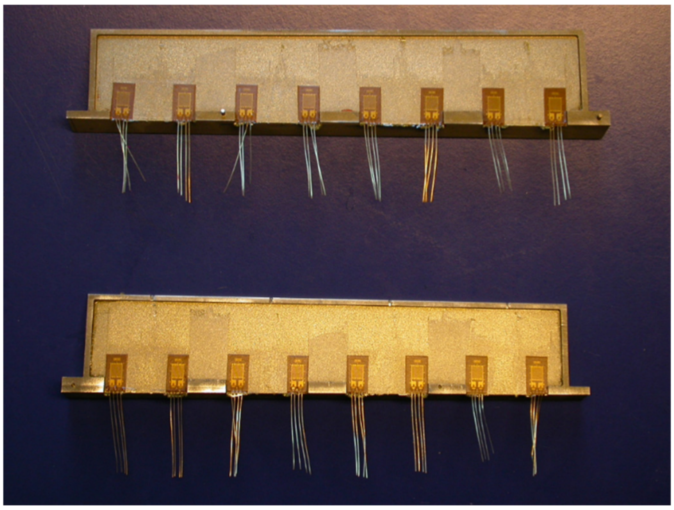


Figure 1 *The force sensor before assembly.*

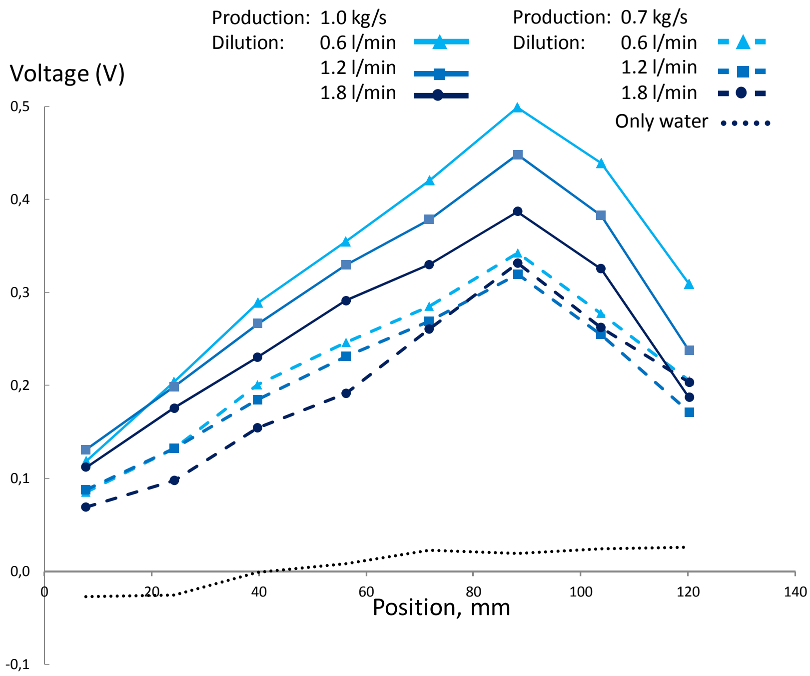


Figure 2 *Strain time average (proportional to the voltage) versus position along the sensor.*

Publications

- Gradin, P. A., Berg, J. E., & Nyström, S. K. (2016). ***Measuring Tangential Forces in a Pulp Refiner: A Novel Approach.*** Experimental Techniques, 40(2), 789-793.
- Sandberg, C., Berg, J.-E. and Engstrand, P**,** (2016): ***System Aspects on Low Consistency Refining of Mechanical Pulp,*** Int. Mech. Pulping Conf. Proceedings, TAPPI PRESS, Atlanta, GA, p. 485-495.

Mathias Lundberg
Industrial PhD

within Forest as a Resource Industrial College FORIC

Research results

Monitoring and controlling of pulp processes by online measurements is a necessity when pulp mills need to be more cost effective to meet today´s competition. High demands are therefore put on the measuring devices characterizing the production. Reliability and validity are key features for stable and accurate measurements that further enables the control of the process for uniformity. A uniform production close to specification targets are highly relevant actions that cut the production cost at the mill.

In a refining process, fine material is created due to the peeling action on the fiber surface. Fiber morphology changes are commonly characterized using camera technology and image analysis. The smallest fraction of the fines, the crill, also created in the refining are too small to be visible in a camera image. The measurement of crill is therefore carried out using an analog method with light sources in the UV and IR wave length spectrum.

The focus has been to answer if the crill can be characterized in the presence of large fines material in a high yield pulp (HYP) refining process. The results showed that the impact of the larger fines material was low. In addition, the variation in the crill measurements becomes lower when fiber treatment increases and remained low during a longitudinal period. The outcome of this year´s study therefore enables the use of the crill method to increase the knowledge in fiber treatment during refining.

The use of relevant measurements in the characterization are important to gain information about the process. More (reliable) information will improve the decision making in the control of the pulping process. A combination of conventional image analysis methods with crill, have the potential to improve the understanding and overall fines material control.

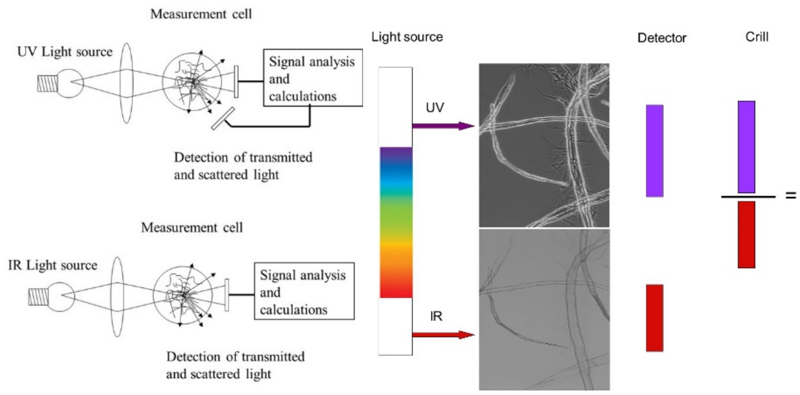


Figure 1. Setup and principle for the crill measurements. UV and IR light illuminates the sample and the transmitted light received by the detectors are measured. The detector for the UV detects the fiber and crill part while the IR detector receives information of only the fiber part. The relation between the specific surfaces in the UV and IR range are used in the calculation of the crill in the pulp sample.

Publications

- Osong S.H, Norgren S, Engstrand P, Lundberg M, Hansen P (2014) ***Crill: a novel technique to characterize nano-lignocellulose.*** Nord Pulp Pap Res J 29(2):190–194
- Osong S.H, Norgren S, Engstrand P, Lundberg M, Reza M & Tapani V (2016) ***Qualitative evaluation of micro fibrillated cellulose using the crill method and some aspects of microscopy.*** Cellulose, Vol. 23(6), p. 3611(14)

List of co-production activities

- MiUn – part of DUVA-project – Göran Thungström
- MiUn – part of e2cmp-project– Per Engstrand

Dr. Sven Norgren

Research results 2016

2016 was a year with several ongoing projects with different financiers. I have also attended to some interesting conferences, IMPC, Papercon etc. I will give you some insight to the projects:

Advanced HYP for paperboard: The project started in April 2015 in cooperation with SCA Östrand, Stora Enso and Valmet and financed by KK foundation. The project goal is to develop and demonstrate techniques, based on hardwood (CTMP) particularly birch, to be used in manufacturing of paperboard. The total energy consumption in refining of such hardwood CTMP should be lower than 700 kWh/ton, to be compared to about 1200 kWh/ton in standard CTMP manufacturing. At present a main obstacle to use birch CTMP in some paperboard quality a high content of extractives. These can cause problems with smell and taste from the packaging material. Improved techniques have to be developed to make birch CTMP an attractive complement to spruce CTMP for the paperboard industry. Recently, two different full scale trials at SCA Östrand were performed, where HT-CTMP (high-temperature) from birch was manufactured. Analyses of extractives from different positions in the mill were examined. A pilot plant trial at Valmet has also been carried out together with Valmet and Stora Enso Research, where LC-grinding on different birch pulps were studied.

E2CMP: A synergy project financed by KK foundation. The purpose of the Project, e2cmp, is to combine an open and lightweight fibre network with strong fibre-to-fibre adhesion to produce a board material that has improved properties. The basic idea is to maximally benefit from the natural stiffness of wood fibres and achieve the required strength properties by engineering the surface properties of fibres since high bulk is the crucial factor that controls the rigidity of the packaging material. We are also aiming at improving the competitive advantage of pulp fibre based over fossil-based plastic materials. Part one of this project have the goal to preserve the fibre morphology by fibre softening and chip refining intensity optimization. First pilot trials will be done in beginning of 2017.

Strong paper from CTMP: This project were founded by Åforsk and Swedish Energy Agency during 2016. In this project several experiments at More Research in Örnsköldsvik were done. Sheets from spruce CTMP fibers were surface treated with a mix of cationic starch and CMC and blended with 20% bleach softwood chemical pulp fibers before handsheets were prepared in a Rapid Köthen sheet former. The sheets were pressed in a hot press nip in a pilot machine with adjustable pressure and heat. Both low and high nip pressure were used in combination with different nip temperatures. Results show remarkable improvements are possible, both in terms of tensile index (up to 85 kNm/kg), see figure 1, and compression strength, SCT, (up to 38 kNm/kg) on CTMP-based sheets under optimal conditions at papermaking, i.e. consolidate the sheet structure in a press nip at evaluated temperatures.

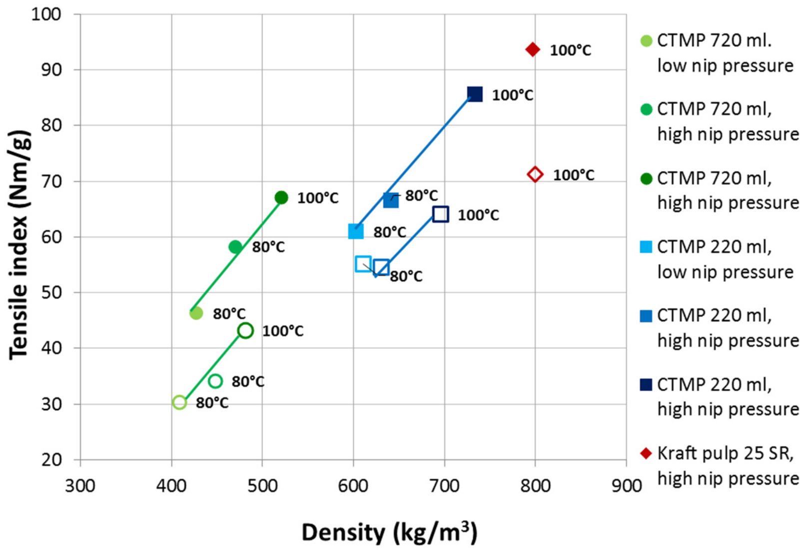


Fig 1. *Tensile index values of sheets made from two different CTMP pulps (CSF 720 ml and 220 ml) blended with kraft pulp at 80/20 mixtures. The fibers in the sheets were either untreated (unfilled icons) or treated with starch/CMC (filled icons). Effects of a low and a high nip pressure at two different temperatures are shown.*

Other activities

I have been assistant supervisor to PhD student Sinke Henshaw Osong and working with studies within the field of nano ligno cellulose. Sinke defended his Doctoral Thesis in April 2016.

Publications

- Pettersson, G, Norgren, S Höglund, H and Engstrand, P (2016). ***Low Energy CTMP in Strong and Bulky Paperboard Plies*** *Tappi Papercon-May 15-18, 2016 Cincinnati, USA*
- Osong, S. H., Norgren, S., Pettersson, G., Engstrand, P., Còrdova, A., Afewerki, S. & Alimohammadzadeh, R. (2016). ***Processing of nanocellulose and applications relating to CTMP-based paperboard and foams.*** *International Mechanical Pulping Conference 2016, IMPC Jacksonville, USA. S. 87--93.*
- Pettersson, G., Norgren, S. & Höglund, H. (2016). ***Strong paper from spruce CTMP.*** *International Mechanical Pulping Conference 2016, IMPC Jacksonville, USA. S. 229--233.*
- Osong, S. H. , Dahlström, C. , Forsberg, S. , Andres, B. , Engstrand, P. , Norgren, S. & Engström, A. (2016). ***Nanofibrillated cellulose/nanographite composite films.*** *Cellulose (London), vol. 23: 4, ss. 2487-2500*
- Osong, S. H. , Norgren, S. , Engstrand, P. , Lundberg, M. , Reza, M. & Tapani, V. (2016). ***Qualitative evaluation of microfibrillated cellulose usingthe crill method and some aspects of microscopy.*** *Cellulose (London), vol. 23: 6, ss. 3611-3624.*

Robert Norgren
Industrial PhD

within Forest as a Resource Industrial College FORIC

New use of bio sludge from pulp and paper industry

The pulp and paper industry generates large amounts of bio-sludge at waste water treatment plants. It is wet and has no obvious economic value, so present industrial focus is not on recycling methods but on disposal. Common disposal methods are incineration and composting (Sivard et al., 2013 Figure 10). In Sweden and Norway about half of this sludge is incinerated and the other half is composted. In Finland almost all bio-sludges is incinerated whereas landfilling of the sludge is common in Chile where half the sludge is landfilled and the other half is incinerated (Sivard et al., 2013 Figure 10a-d). Biomass waste in general could be recycled for its energy content or as a resource for chemical products or solid materials. New solutions should apply to circular economy thinking.

Norgren et. al. (2015) performed a literature study and compiled a list of 23 novel methods for recycling bio-sludge. They were assessed for their technical maturity and degree of circularity (circular economy-thinking). They concluded that the production of single cell protein (SCP) and a lead absorber, from these three perspectives, were the two more suitable methods. An alternative to the SCP method could be larvae's of black soldier flies (BSF) which could constitute a source of protein for animal feed besides degradation of organic waste (Diener et al., 2011, pp. 357, 358).

The focus of 2016 have been to assess the potential of bio-sludge as feed for BSF larvae from the perspective of suitability and economic drivers. Sludge from ten Swedish mills were studied and their content of useful substrates and detrimental content like heavy metals were analysed.

In Figure 1 the complete results of the chemical analysis are displayed. The content of nutrients and useful substrates are displayed as normalized values, setting the highest measured value to 100.

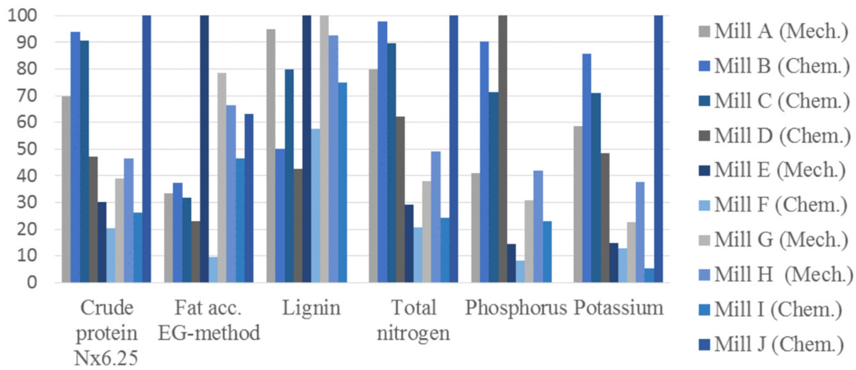


Figure 1 Sludge content of resources. Standardized values.

In Figure 2 the theoretical maximum economic value of six substrates potentially derived from the sludge is displayed together with the uncertainty. The uncertainty is influenced by the method used for laboratory analysis and the range of economic value. For the protein, lignin and fat, it is the economic value that represents the greatest uncertainty but for the rest of the parameters it is the uncertainty of the analysis that is displayed. In addition to the substrates in the figure, the total carbon was analyzed but only for one mill (J), and is therefore not displayed in the Figure. Of the dry substance the total carbon was 46 % which corresponds to 900 EUR/ton DS if it could be converted to activated carbon. Negative values for sludge as biofuel are obtained for two of the mills (C, J).

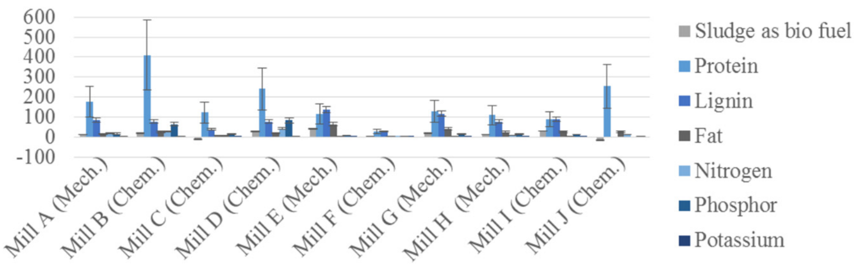


Figure 2 Potential economic value as driver for circular economy solutions (EUR/ ton DS of sludge)

Oonincx et al. (2015) tested four different feeds derived from food waste for breeding BSF larvae. They analyzed the content of crude protein, phosphorous and total fatty acids (TFA) on a dry matter basis (2015, p. 5).

Their conclusion were that (2015 Figure 1) a high protein and high fat (HPHF) diet is better for the larvae than a low protein, low fat diet. Therefore HPHF is used for comparison with bio-sludge. Please note that TFA is not directly comparable to fat according to 2009/152/EU mod. The TFA method probably results in a lower value then what the EU-method would for the same sample (Åkerlind, 2009, p. 3). For mill I the phosphorus bar is not visible because of the very low value.

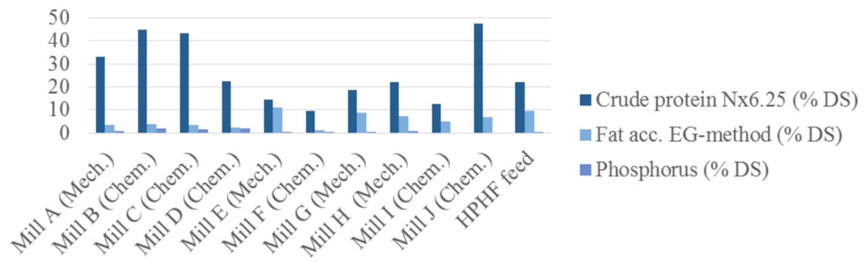


Figure 3 Suitability of sludge as BSF feed

The dry substance of prepupae of BSF contains about 43-44 % of protein (Diener et al., 2011, p. 358), (Čičková et al., 2015, p. 74). This has been used for calculating the amount of prepupae from the produced amount of protein. The worst case scenario for the concentration of Hg, Cd and Pb in the prepupae have been calculated by dividing the total Hg, Cd and Pb content in the sludge with the amount of prepupae. The results are compared to the limit values of the European Union for animal feed (Nordin and Wejdemar, 2014, p. 6), (European Commission, 2011, p. 9). The results are shown in Figure 4.

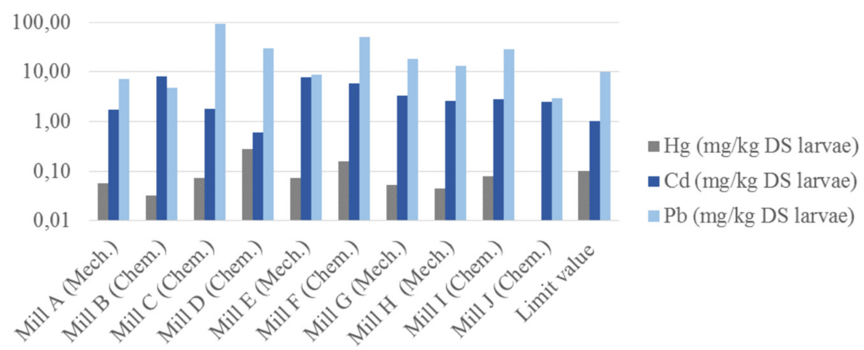


Figure 4 Theoretical maximum content of metals in prepupae

The results from this year's work can be summarized as follow. There are considerable differences in concentration of useful substrates in bio-sludge from the mills in this study. Mills that are developing and implementing methods to recycle resources from bio-sludge should consider these differences and the potential benefits of economy of scale, efficiency, etc. by cooperating with other mills.

The economic driver often sets protein as the most valuable substrate but lignin can for some of the mills be more valuable. On the other hand depending on the technology applied the rate of extraction of recyclables can change and as a result, also the most preferable recycling option. The market value of the product also has the potential to change the most valuable recycling option. In the longer term production of activated carbon may be an even more valuable option than protein.

Assessing the suitability of bio-sludge as BSF feed by comparing the protein to fat quota shows that bio-sludges from mill E, G, I and H are more similar to a proven suitable HPHF feed than the other sludges compared. The fate of the metals Hg, Cd and Pb in the production process might be a problem and the limit values for animal feed may in a worst case scenario be exceeded.

Hans Höglund, senior professor

During 2016 I have assisted in three projects as senior advisor to guarantee continuity and efficient transfer of knowledge from previously accomplished research in specific fields of interest. In all three projects it has been possible to use results from previous more fundamental research projects to demonstrate new technologies that are of interest to apply in paper industry companies, which use mechanical and chemimechanical pulps as raw material in there production.

In the project **"Improved energy efficiency in refining of softened TMP fibers"** *(Birgitta Engberg is project manager)* mill evaluations have been carried out of fundamentally new types of refiner plates, which have been developed for refining of soften wood fiber material in disc refiners. The design is based on research results from studies in pilot plant scale at Valmet R&D Centre during the past 10 years. A set of refiner plates with the new design has been tested in the Ortviken TMP mill with very promising results regarding the potential to save electric energy. The mill scale trials, with the objective to implement the new technology in mill size refiners, will continue during 2017 in cooperation with several industrial partners.

In the project **"Advanced HYP for paperboard"** *(Gunilla Pettersson is project manager)* a technology is exploited with hardwood HT-CTMP (high temperature chemimechanical pulps) as wood raw material, which originally was developed for manufacturing of bulky middle plies in multiply paperboards from spruce CTMP. The technologies make it possible to use HT-CTMP, which can be produced at a very low energy input in chip refining (about 600 kWh/ton), in manufacturing of stiff light-weight packaging materials with high bending stiffness. Implementation of these technologies means savings of both wood raw material and electric energy. A mill scale evaluation of the technology with birch as raw material is imminent.

In the project **"Strong papers from spruce CTMP"** *(Gunilla Pettersson and Sven Norgren are project managers)* the opportunity to manufacture strong paper products even from high yield pulps (HYP) with a high content of lignin is evaluated. To achieve that goal using HYP, which can be manufactured with comparatively low consumption of electric energy, the conditions in papermaking have to be changed. Old appropriate knowledge about the visco-elasticity of lignin at high temperatures is utilized. In laboratory and pilot plant trials it has been shown that paper strength properties from HYP furnishes are improved significantly at pressing of paper webs at suitable dry content in hot press nip at temperatures well above the softening temperature of lignin. At such conditions papers from spruce CTMP can be manufactured with the same tensile strength and the same or better compression strength (SCT) than papers from bleach softwood kraft pulp furnishes. It is obvious that it is a great yet unexploited potential in papermaking from spruce HYP furnishes, which could be utilized in manufacturing of products where very high requirements upon strength is demanded. How these findings can be exploited in the best way in full scale papermaking concepts is now discussed with interested industrial partners. Different ways to make close to full scale trials are under considerations. A manuscript that sum up results from the project has been accepted for publication in NPPRJ (Nordic Pulp&Paper Research Journal). A patent application of the technology has been made.

Publications

- Pettersson, G. , Norgren, S. & Höglund, H. (2016). ***Strong paper from spruce CTMP.*** I *International Mechanical Pulping Conference 2016, IMPC 2016*.. S. 229--233.
- Pettersson, G. , Norgren, S. , Höglund, H. & Engstrand, P. (2016). ***Low energy CTMP in strong and bulky paperboard plies***. I *Paper Conference and Trade Show, PaperCon 2016*.. S. 556--564.

Thomas Granfeldt
Adjunct Professor

(sponsored by Valmet AB)

2016 has been a hectic year where my main activity has been acting both as board member and sub project leader in the e2mp, e2cmp/Synergy and A-HYP projects.

Within e2mp in the project "Refining of softening TMP fibers" together with SCA, Stora Enso, Holmen and Valmet we are developing a non-conventional refiner segment in order to reduce the specific energy consumption in refining. The stage has presently been taken from promising results in pilot plant scale to confirming these in a series of mill scale trials at SCA Ortviken. The trials will continue throughout 2017.

The Synergy project e2cmp, together with Billerud Korsnäs, PulpEye and Valmet, is aiming for a new type of bulky softwood CTMP that will be developed in parallel to a new concept for making paperboard. Much efforts have been spent during the year for planning and setting up the different sub projects. The practical part with bench marking and pilot plant trials has just started.

In the project A-HYP, Advanced high yield pulp for paperboards, together with SCA Östrand, Stora Enso and Valmet we have made several mill and pilot plant trials for reaching a specific energy reduction in refining of birch (and eucalyptus) CTMP for paperboard by about 40% by utilizing high temperature technology and low consistency refining. The project is running towards its end and it looks like the 40% are reached.

On top of this I have supported Johan Franzén (Valmet) who is the industry project leader for the project Mod-DD refining – 50% electric energy reduction at doubled production. I have also been working in the reference group of Eric Nelsson who defended his thesis Reduction of Refining Energy during Mechanical Pulping in April.

The research work has resulted in one published paper.

Publications

- Nelsson E. , Sandberg C. , Svensson-Rundlöf E. , Paulsson M., Granfeldt T. , Engberg B. and Engstrand P. (2016): ***Mill scale production of TMP with double disk refining – The effects of a mild sulfonation, atmospheric preheating and refining temperatures***. Proc. 29th Int. Mech. Pulp. Conf., Jacksonville, FL, USA, September 26-28, 11pp.

Per Bergström, PhD student

Fibre Network Design: Applications to Hygiene Products

Low density fibre networks play significant roles in many man-made materials such as paper, tissue, wipes and diapers and absorbent hygiene products. The mechanical properties such as resistance to tension and compression of the network in these structures play a vital part for both product properties and production of the products.

We have created a micro-mechanical model of low density fibre networks in order to increase knowledge regarding macroscopic properties of the material in relation to single fibre properties and properties of the network.

In this model each individual fibre in the network is modelled in three dimensions using a Discrete Element Method (DEM) where fibres are constructed by a string of bonded particles to represent the geometrical features of the fibre such as fibre length, fibre diameter and shape. Each pair of bonded particles can undergo stretching, compression, shearing, bending and twisting due to their relative linear and rotational motion. The properties of these bonds can be set to represent the bending stiffness, twisting stiffness, shear stiffness and elastic modulus for compression of the fibre. By using the DEM model to deposit fibres by gravity we are able to generate a realistic network and capture network properties such as fibre orientation, porosity and homogeneity.

The benefit of this is a very detailed view of the mechanics working in the fibre material and a tool for in depth understanding the behavior of fibre network materials. We are currently applying this to understanding tensile strength in the network on a fibre level and questions such as what constitutes strength of the material and what is the cause of failure.

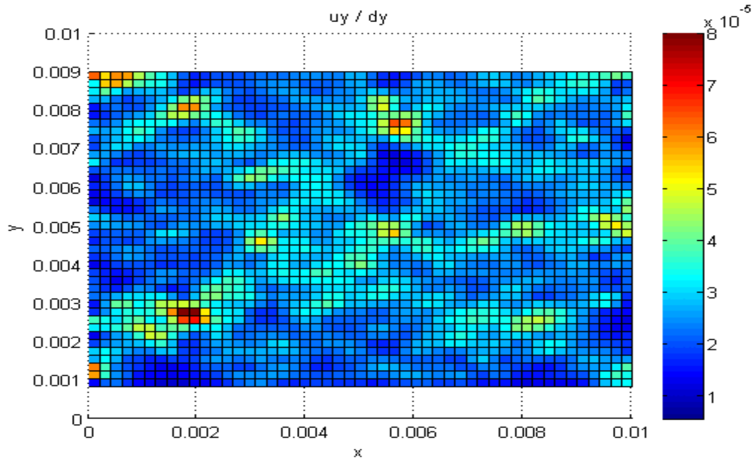


Figure 1: Strain field in network.

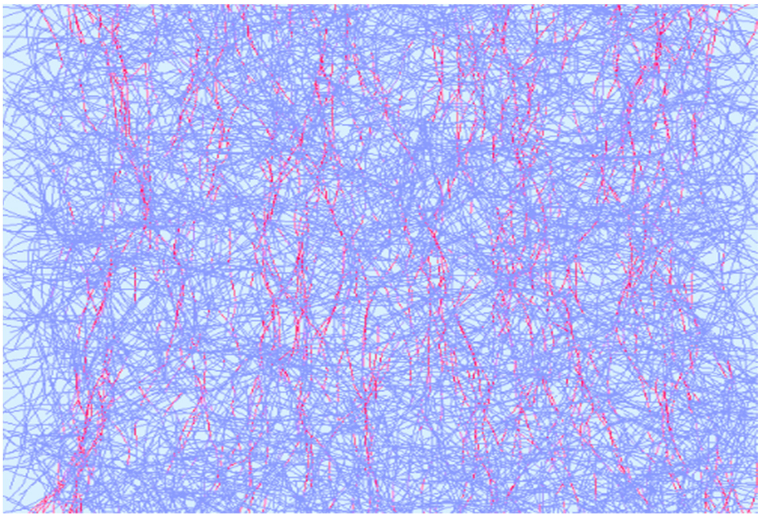


Figure 2: Fibre strain in individual fibres

Carolina Costa, PhD Student

Research results 2016

I have a Master Degree in Biomedical Engineering and my main focus is on biomaterials. I did my Master thesis in thermoresponsive polymers, in the Colloid's Group of the Chemistry Department of the University of Coimbra, in Portugal. Afterwards, I continued working there in a research project involving dissolution and regeneration of cellulose in water-based solvents, where Björn Lindman was involved, and moreover, the extraction of nanocrystals from different cellulose sources.

I became a PhD student at Mid Sweden University in May 2016, in the research group of Surface and Colloid Engineering with Magnus Norgren and Håkan Edlund as supervisors. Following the Björn Lindman´s hypothesis that cellulose is an amphiphilic polymer, my research project is mainly centered in the adsorption behavior of native dissolved cellulose at oil-water interfaces (as in emulsions) and its possible ability of acting as a good dispersion stabilizer.

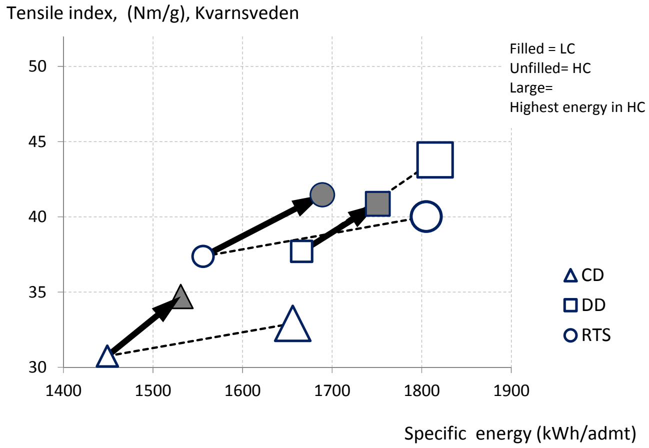
Typically, a surfactant is used as the dispersant and a polymer as stabilizer. Some amphiphilic polymers, like cellulose derivatives, can fulfil both actions. Methyl cellulose, hydroxyethyl cellulose and ethyl hydroxyethyl cellulose are well known as efficient stabilizers of emulsions (and suspensions), but it would be a clear advantage to use cellulose itself without chemical modification. Initial experiments have been showing very promising results and stable O/W emulsions have been achieved.

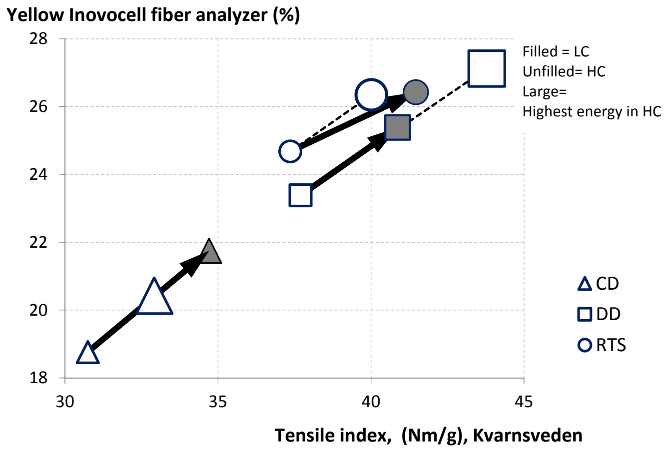
Rita Ferritsius, project leader

Could pulp strength be assessed faster based on fiber properties?

I have been working with both chip and fiber refining and with fiber properties for both high and low consistency refining within the sphere, e2mp, for reduction of energy in TMP refining. Some of these results were presented in five different papers at international mechanical pulping conference (IMPC 2016) in Jacksonville, see reference list below. In the project: "Fiber properties in HC and LC refining", samples from three TMP lines were analyzed. Two of the lines were in Kvarnsveden and one was in Hallstavik. These three lines had different type of both chip and LC refiners. Tensile index versus specific energy is shown for the samples in the figures on next page. This shows that the specific energy for certain tensile index could be very different. The sheetmaking and tensile index testing is very time consuming especially if proper statistic should be obtained when optimizing in mill or investigating new concepts for reduction of specific energy. Both mill and research organization are reducing manpower more and more and it is therefore important to find less time consuming methods which could give a detailed information of the fibers which could be correlated to strength properties. Today it is possible to make fast measurements of the fiber dimensions, but still it is missing methods to get fast measurement of the properties of the fiber wall.

In order to try to find such a method these samples were also used in another project where an old time consuming method Simon Stain (intended for measurement of the fiber wall properties by using two different colored polymer of different size) was tried to be transformed to a semi-automatic method. The treatment of the fibers with the colored polymers were made in the same way as in the old method, but the measurement of the fibers were made in a fiber analyzer equipped with a color camera. This improves the statistics considerably while many thousands of fibers can be analyzed instead of 200 fibers as was the case in the old method. These first measurements of the nine pulps in the fiber analyzer were very promising indicating a very good co variation of the percentage of yellow color and measured tensile index of the pulps, se figures. Yellow color indicate that the fiber wall has been treated.





Also measurement of tensile index in a statistically trustable way is very time consuming. A fast fiber measurement including fiber wall properties to be used for predicting strength properties would be very valuable for both optimization in mill and for evaluating research projects. Although the preliminary results were promising some more research work has to be made to get a roburst method.

Publications

- Karlström, A. , Hill, J. , Ferritsius, R. & Ferritsius, O. (2016). ***Pulp property development Part II : Process non-linearities and their influence on pulp property development.*** *Nordic Pulp & Paper Research Journal,* vol. 31: 2, ss. 287-299.
- Karlström, A. , Hill, J. , Ferritsius, O. & Ferritsius, R. (2016). ***Pulp property development Part III : Fiber residence time and consistency profile impact on specific energy and pulp properties.*** *Nordic Pulp & Paper Research Journal,* vol. 31: 2, ss. 300-307.
- Reyier Österling, S. , Ferritsius, O. , Ferritsius, R. , Johansson, C. & Stångmyr, J. (2016). ***Weighted averages and distributions of fibre characteristics of mechanical pulps – Part II: Distributions of measured and predicted fibre characteristics by using raw data from an optical fibre analyser.*** *Appita journal,* vol. 69: 1, ss. 64-73.
- Ferritsius, R., Sandberg, C., Ferritsius, O., Rundlöf, M., Daniel, G., Mörseburg, K. & Fernando, D. (2016). ***Development of Fiber Properties in Full Scale HC and LC Refining***. *International Mechanical Pulping Conference 2016*
- Ferritsius, O. , Ferritsius, R. , Hill, J. , Ferritsius, J, .Mörseburg, K., & Eriksson, K, ***"Untaught experiences regarding common practice and standards for sampling, characterization, control, and Design of TMP and CTMP operations"*** International Mechanical Pulping Conference 2016, IMPC 2016.. S. 12—17
- Johansson, O. , Fernando, D. , Fenitsius, R. , Daniel, G. & Ferritsius, O. (2016). ***" Advancements in optical analysis yields new insight to mechanical pulping processes in an efficient and inexpensive way***". I *International Mechanical Pulping Conference 2016, IMPC 2016*.. S. 267—276.
- Eriksson, K. , Ferritsius, J. , Ferritsius, O. , Ferritsius, R. , Hill, J. , Karlstrorrp, A. & Merseburg, K. (2016). ***"Proper pulp sampling pre-requisite to any pulp property assessment."*** I *International Mechanical Pulping Conference 2016, IMPC 2016*.. S. 1--11.
- Eriksson, K. , Ferritsius, R. , Ferritsius, O. & Hill, J. (2016). ***"Benefits from improved stability in process conditions and pulp properties-a double disc refiner case study"***. I *International Mechanical Pulping Conference 2016, IMPC 2016*.. S. 317--327.

Olof Ferritsius, Project leader

What is the Average of Short and Long?

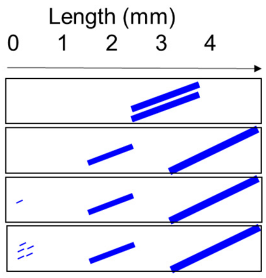
In order to be able to communicate in a clear way and avoid misunderstandings it is vital that we have a common meaning of the words we use. The language “Fiberish” has many words we use frequently, which lack a clear, common definition e.g. “energy efficiency”, “pulp quality”, “fiber development” and “fiber length”. Each of these words have a wide variety of different meanings among researchers and mill employees.

I will show you a case, which I presented in one of my three oral presentations at the International Mechanical Pulping Conference in USA. This case deals with how to express “fiber length”, a fundamental factor for pulp characterization. Of the four words mentioned above this may be the easiest to assess. How difficult can it be to measure length? Well, the challenge is not to measure the length of a single wood fiber or particle. It was done almost a century ago, manually in a microscope and during the last decades using automated optical analyzers. The big challenge it to assess the *average* fiber length of a pulp. This is a problem because the particles exhibit such a wide range in length, from almost invisible fines all the way up to really long fibers, about 6 mm.

Perhaps most straight forward is to use the arithmetic average, commonly called the mean value. This is what we in daily life refer to as "the average". Here the sum of the length of all measured particles is divided by the number of measured particles. The shortest particle has the same impact on the average as the longest one, but the *number* of fines are huge compared with the number of longer and heavier fibers. Weighted averages, on the other hand, are based on a calculation where some data points are given more weight than others. If each fiber (or particle) is given such a weight based on its length, the longer fibers will exert a higher impact on the average. The longer fibers will influence the average even more when the length-weights are increased, for example by using the length in square. If we wish to use "average fiber length" as a measure of the presence of long fibres in a pulp, we need to use an average that give a reasonable description of this.

It was reported in 1928 that the arithmetic average would underestimate the presence of the long fibers in a pulp. In 1942, Clark stated that “*Fiber length measurements should, as accurately as is practical, be a measure of the weighted average fibre length by true weight*.” Luckily, it is possible to get an estimate of this average without measuring the weight of each fiber. The length-length-weighted average is actually such a value. We have found in one of our projects that the average length-length-weighted fiber length is a relevant parameter of the “length” factor of a pulp while the length-weighted average may lead to erroneous conclusions.

How to assess the amount of long fibers using "average fiber length" can be demonstrated using a simple model, we may consider four hypothetical pulps A, B, B1 and B2, as shown in the figure below.



Pulp:	Average length (mm) Arithmetic	Length-weighted	Length-length-weighted
A	3.0	3.0	3.0
B	3.0	3.3	3.60
B1	2,1	3.2	3.59
B2	1.1	2.7	3.53

Pulp A consists of two fibers, both 3 mm in length. Pulp B consists of one longer fiber with a length of 4 mm and a shorter with a length of 2 mm. Both pulps have an arithmetic average length of 3.0 mm, but pulp B have longer weighted averages, both length-weighted and length length-length-weighted, because of the longer fiber in pulp B.

If pulp B is refined to become pulp B1 in such a way that one piece, 0.30 mm long, come loose from the wall of one of the two fibers the mean fiber length will drop considerably from 3.0 to 2.1 mm which is *lower* compared to pulp A. The average length-length-weighted length will only be reduced marginally by 0.01 mm. This shows that pulp B and pulp B1, which look quite similar in the figure, also have almost the same length-length-weighted average. To further illustrate how the amount of fines may fool us in assessing the amount of longer fibers, please imagine pulp B2 which has five times higher amount of 0.3 mm long particles than pulp B1. The arithmetic average is as low as 1.1 mm and the length-weighted average drops considerably from 3.2 to 2.7 mm, which is lower compared with pulp A. The length-length-weighted average will only be slightly reduced to 3.53 mm. This is obviously the measure with the strongest relation to the content of long fibres, at least of those investigated here.

Why then is it important to have a more relevant way to express the fiber length of a pulp? When trying to run a mechanical pulping process as energy efficiently as possible, one way is to operate very close to the quality limits. Efforts to reduce the specific energy input often leads to a reduced amount of long fibers and a lower average fiber length. The possibilities to reduce the specific energy input in refining will increase if a lower average fiber length can be accepted in paper and board products. Therefore it is of utmost importance to have relevant and reliable measures of the average fiber length. It should be stressed, to avoid further misunderstandings, that fines are important but not for the same pulp characteristics as the long fibers.

So what is the problem? The problem is that the scientific community as well as mills and suppliers almost exclusively (97 %) use the length-weighted or arithmetic average fiber length, which are shown above not to be particularly useful as a measure of long fibres. There is to the best of my knowledge no evidence in scientific papers that justifies the use of the length-weighted average. Some references in the scientific papers can be traced back to personal communication, including rumors spread by suppliers, but lacks data or discussions. A method is not relevant because it has been used for a long time by many people. But, as mentioned above, there are excellent scientific studies from way back in time, on how to assess the average fiber length. Let us use such "words" when speaking more proper "Fiberish"!

Hopefully, within a short time from now, we can arrive at a common concept with a useful measure of the amount of long fibers present in a pulp based on a common understanding of the values used. As can be truly said about fiber length: the average of short and long is *not* medium. The average is almost as long as long.

Publications

- Karlström, A. , Hill, J. , Ferritsius, R. & Ferritsius, O. (2016). Pulp property development Part II : ***Process non-linearities and their influence on pulp property development.*** *Nordic Pulp & Paper Research Journal,* vol. 31: 2, ss. 287-299.
- Karlström, A. , Hill, J. , Ferritsius, O. & Ferritsius, R. (2016). ***Pulp property development Part III : Fiber residence time and consistency profile impact on specific energy and pulp properties.*** *Nordic Pulp & Paper Research Journal,* vol. 31: 2, ss. 300-307.
- Reyier Österling, S. , Ferritsius, O. , Ferritsius, R. , Johansson, C. & Stångmyr, J. (2016). ***Weighted averages and distributions of fibre characteristics of mechanical pulps – Part II: Distributions of measured and predicted fibre characteristics by using raw data from an optical fibre analyser.*** *Appita journal,* vol. 69: 1, ss. 64-73.
- Ferritsius, R., Sandberg, C., Ferritsius, O., Rundlöf, M., Daniel, G., Mörseburg, K. & Fernando, D. (2016). ***Development of Fiber Properties in Full Scale HC and LC Refining***. *International Mechanical Pulping Conference 2016*
- Ferritsius, O. , Ferritsius, R. , Hill, J. , Ferritsius, J, .Mörseburg, K., & Eriksson, K, ***"Untaught experiences regarding common practice and standards for sampling, characterization, control, and Design of TMP and CTMP operations"*** International Mechanical Pulping Conference 2016, IMPC 2016.. S. 12—17
- Johansson, O. , Fernando, D. , Fenitsius, R. , Daniel, G. & Ferritsius, O. (2016). ***" Advancements in optical analysis yields new insight to mechanical pulping processes in an efficient and inexpensive way"***. I *International Mechanical Pulping Conference 2016, IMPC 2016*.. S. 267—276.
- Eriksson, K. , Ferritsius, J. , Ferritsius, O. , Ferritsius, R. , Hill, J. , Karlstrorrp, A. & Merseburg, K. (2016). ***"Proper pulp sampling pre-requisite to any pulp property assessment."*** I *International Mechanical Pulping Conference 2016, IMPC 2016*.. S. 1--11.
- Eriksson, K. , Ferritsius, R. , Ferritsius, O. & Hill, J. (2016). ***"Benefits from improved stability in process conditions and pulp properties-a double disc refiner case study"***. I *International Mechanical Pulping Conference 2016, IMPC 2016*.. S. 317--327.

MD, Shakhawath Hossain, Post Doc

I am currently working in the project 'Fibre network design: Application to hygiene products' with Prof. Tetsu Uesaka in the Complex Materials research group. Low-density fibre network is typically seen in tissue paper, paper towel, and absorbent core of personal-care products. Such network is also the main structural framework for many living systems e.g. cells, tissues etc. Therefore, it is important to understand the deformation mechanics of such fibre network which mainly depends on the density, connectivity and topological features of the network structure. In this research project, I am investigating the micro-mechanical deformation behaviour (in-plane tension, ZD compression, creping, shearing under compression) of the fibre network for design/redesign of cellulose fibre based products.

In order to represent such fibre network and to resolve the complex interplay among different micromechanical deformation modes during compression, we have modelled the system by using the discrete element method (DEM). Typically, the fibres are complex in shape with various curl, kink and twist. To represent the realistic features of fibres within the DEM framework, a series of linked or bonded particles are required. The fibre networks are generated by a gravity-deposition process of a dilute fibre suspension as shown in figure 1. One of the key characteristics of such fibre network is anisotropy - fibres are mostly oriented in the plane direction.

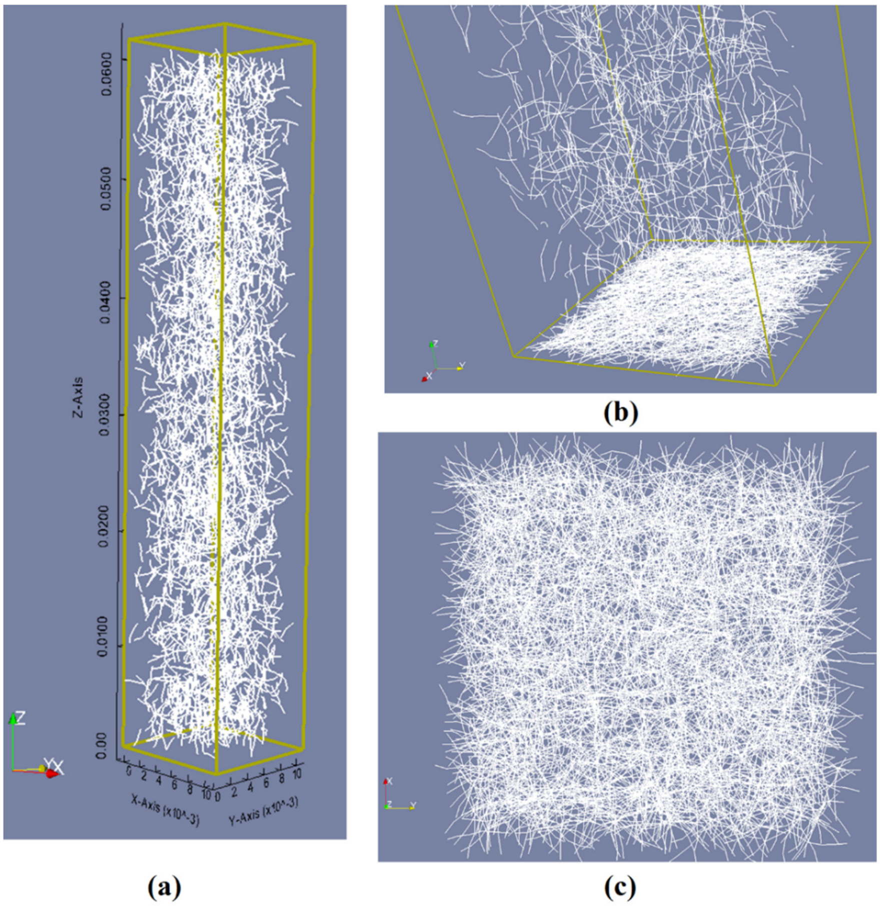


Figure 1: a) Initial configuration of fibres placed randomly in a 3D space (axis units are in meters), b) fibres depositing on the virtual floor under gravity with drag force, c) top view of the model fibre network

From the micromechanical investigation of the fibre network structures, we have achieved important information such as in ZD compression, non-affinity and anisotropy of the soft fibre network plays an important role and constitutes softness of typical tissue, towels etc. Also, the non-uniformity of the network structure plays the most important role in tensile failure.

Presentations

International conferences

Hossain, M. Shakhawath, Bergström, P. and Uesaka T. ***Computational material design of low-density fibre network***. Provisionally accepted in 16th Fundamental Research Symposium, Pembroke College, Oxford, UK, September 3-8, 2017.

Hossain, M.S., Bergström, P. and Uesaka T. ***A particle-based model to investigate the mechanics of soft fibre network***. European Congress on Computational Methods in Applied Sciences and Engineering (ECCOMAS), Crete, Greece, June 5-10, 2016.

Public reach

Hossain, M. Shakhawath, ***"Soft Matters: Cellulose Fibres in the Future",*** Science and Innovation Days, Sundsvall, Sweden, Oct., 2016.

Rizan Rahmani, PhD Student

My research is based on the identification of insect pheromones. The research consists mainly analysis of semiochemicals in co-operation with the department of Biology University of Kentucky and Pheromone group, Lund University. Currently I am working on;

Purification and analysis of pine sawflies pheromone.

In this project extracts are purified by solid phase extraction column (SPE) and then derive with optically pure chiral agents to do the stereoisomeric composition GC-MS analysis of pheromone.

The aim of the present study is to develop a method, based on chiral derivatization and analysis by GC-MS, by which stereoisomers of chiral alcohols found in whole body extracts from female pine sawflies can be determined and quantified.

The carrot psyllid (T. apicalis) is one of the major pests of carrot (Daucus carota) in northern Europe.

Extraction, purification and analysis of biological active compounds that is responsible for observed insect behavior which indicates chemical communication between carrot psyllid species.

In this project main goal was purification of active compound which was done by Preparative Gas Chromatography; method was developed for the separation of volatile components from the extract.

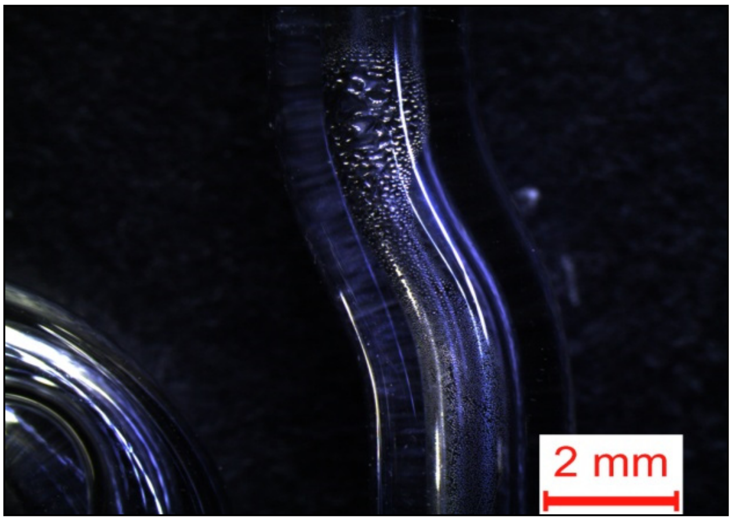


Fig 1. (PFC) Preparative fraction collector (one of the traps for collecting compounds).

After purification of active compound, further analysis is done by NMR to do the structure elucidation. The goal of our project is to "*develop efficient, commercial successful control methods for pest insects, based on semiochemicals.*

Bo S. Westerlind, Researcher

Plasticised paper for replacing plastics from fossil-based resources

Vulcanised paper has been around for 150 years. Typically, it was used for suitcases, boxes, interior parts for cars and today it is still used for gaskets and in the electro technical industry because of good dielectrical properties. It is made of cotton linters and chemically treated with 70 weight percent of zinc chloride in water at around 40-72 °C. The higher the temperature is the shorter the treatment time will be. Vulcanised paper is made on low speed paper machines where the paper web after it is formed goes through a heated bath of zinc chloride and water. A current stream washer removes and recycles the zinc chloride from the paper web and then a drying unit dries the vulcanised or plasticised paperboard. Environmental issues with zinc chloride, high production costs and competition from plastics have made the production of vulcanised paperboards to decrease since the 1950´s and the production now is limited to small volumes. The interesting thing with vulcanised or plasticised paper is that strain at break is twice as high as normal paperboards and compared to recycled paperboards the specific tensile strength is almost twice as high. This in combination with a high wet strength make plasticised paperboards to expand the use of cellulose-based products. In some applications, it can replace plastics made from fossil-based resources. Plasticised paperboards can be shaped by cutting, drilling and grinding similar to many plastics.

There are other solvents and chemical routes than zinc chloride that can be used for partly dissolving and plasticise cellulose. For example, ionic liquids or sodium hydroxide mixed with urea at sub zero temperatures. The latter system is green and only short reaction times are needed. If the sodium hydroxide/urea system can be efficiently removed and recycled from the paperboard then this might be a possible route for 3D-formed packages and products replacing those made of plastics.

The contribution of lignin to the mechanical strength of softwood fibres are of interest because mechanical pulp a higher yield than chemical pulp where lignin has been removed through the addition of chemicals. Typically, paper made of chemical pulps are stronger and more ductile than papers made of mechanical pulps. This is also true when accessing fibre strength and displacement at break using a zero span tensile tester, where the distance between the clamps is close to zero. In co-operation with Åbo academy we have used a switchable ionic liquid (SIL) to remove the lignin from chemi-thermo-mechanical pulp (CTMP) and compared the mechanical properties measured using zero span tensile tests. Half of the lignin was removed from the CTMP-fibres by the SIL-treatment but almost no changes in zero span tensile strength or displacement at break. If the cellulose fibrils were the only load-bearing element in the cellulose fibre and the SIL-treatment does not affect the fibrils then one would expect that zero span tensile strength and displacement at break would increase when lignin is removed. Chemical pulping involves more effects than just removing lignin since fibre strength and strain at break increase initially in that process while removing lignin by a SIL-treatment of CTMP fibres has no or little effect on fibre strength and strain at break.

Publications

- Piltonen, P. , Hildebrandt, N. C. , Westerlind, B. , Valkama, J. , Tervahartiala, T. & Illikainen, M. (2016). ***Green and efficient method for preparing all-cellulose composites with NaOH/urea solvent.*** *Composites Science And Technology,* vol. 135, ss. 153-158.
- Duan, R. , Westerlind, B. , Norgren, M. , Anugwom, I. , Virtanen, P. & Mikkola, J. (2016). ***Fibre stress-strain response of high temperature chemi-thermomechanical pulp treated with switchable ionic liquids.*** *BioResources,* vol. 11: 4, ss. 8570-8588.

Birgitta Engberg, Docent, Associate Professor

Research results 2016

During 2016 I have been involved in several research projects in the area of high yield pulping technology.

In the project *"Refining of softened TMP fibers"* we are developing non-conventional refiner segments designs in cooperation with Valmet. The objective is to make it possible to refine high yield pulp fibers which have been softened (by for example high temperature or by the use of chemicals) under stable conditions. In conventional refining, using standard refiner segments, there are often problems when refining a softened wood material since the refiner gap needs to be very small and the process therefore gets extremely sensitive for any disturbances. The new developed design is based on research results from studies in pilot plant scale at Valmet R&D Centre during the past 10 years. A set of refiner plates with the new design has been tested in the SCA Ortviken TMP mill with very promising results regarding the potential to save electric energy. The mill scale trials, with the objective to implement the new technology in mill size refiners, will continue during 2017 in cooperation with Valmet, SCA, Holmen and Stora Enso.

In the project *"Pretreatment strategies for high yield pulps"*, pilot and full scale trials were carried out during 2016 to be able to correlate e.g. potential energy reductions in refining due to different pretreatments to the results from laboratory studies using the same pretreatments. In the laboratory studies wood samples that were pretreated or impregnated with different chemicals under different conditions were evaluated by different material testing techniques, primarily shear testing and high deformation rate compression testing in an encapsulated split-Hopkinson pressure bar device. Cooperation with Tampere University of Technology in Finland using high-speed photography during the high deformation rate tests has also lead to better understanding of the dynamic behavior of wood in hot steam environments.

The project *"ModDD – Process modeling and new technical solutions for increased production rate"* was started in January 2016 (cooperation with Valmet). Here particle modeling in combination with other modeling techniques is used to model/simulate the feeding of fiber material into double-disc (DD) refiners. The refiner inlet is an important section to improve when it comes to making the production process of high yield pulps more energy efficient. To drastically improve the energy efficiency of the process, it is our belief that today's production rates need to be substantially increased.

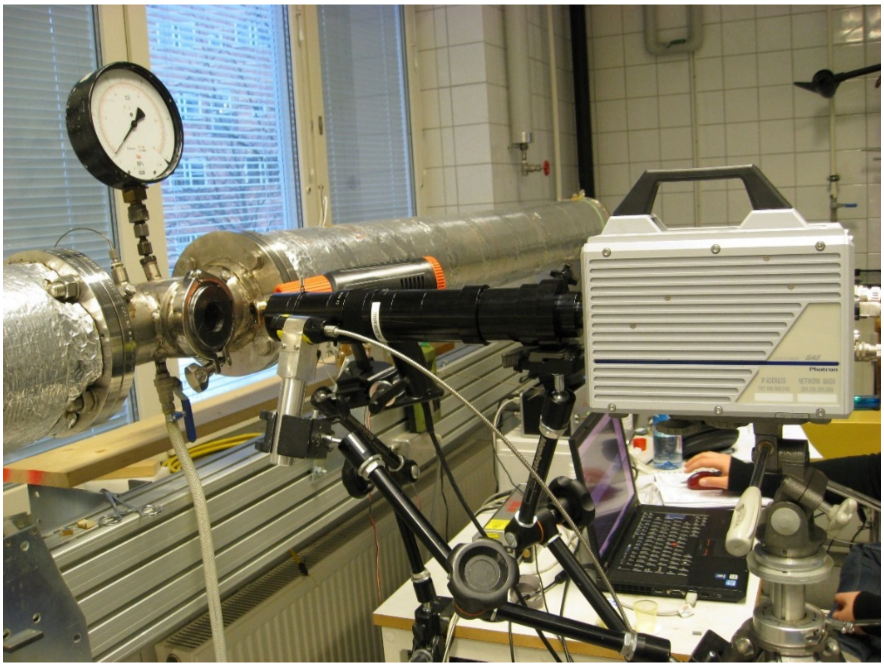


Figure 1. *Photo from lab-scale trials where we used the Split-Hopkinson testing technique to study high strain-rate compression of pre-treated wood in a hot steam atmosphere. To study local compression behavior, we also used a high speed camera and a special laser lightening technique to capture as many image frames as possible during the impulse loading. A cooperation with Tampere University of Technology in Finland.*

Publications

- Moilanen, C.S., Björkqvist, T., Engberg, B.A., Salminen, L.I. and Saarenrinne, P. (2016). ***"High strain rate radial compression of Norway spruce earlywood and latewood".*** Cellulose (London), vol. 23: 1, pp. 873-889.
- Moilanen, C.S., Björkqvist, T., Ovaska, M., Koivisto, J., Miksic, A., Engberg, B.A., Salminen, L.I. and Saarenrinne, P. (2016). ***"Modelling and simulation of radial spruce compression to optimize energy efficiency in mechanical pulping"***. In International Mechanical Pulping Conference 2016, Jacksonville, FL, USA, pp. 18-35.
- Nelsson, E., Sandberg, C., Svensson-Rundlöf, E., Paulsson, M., Granfeldt, T., Engberg, B.A. and Engstrand, P. (2016). ***Mill scale production of TMP with double disk refining-The effects of a mild sulfonation, atmospheric preheating and refining temperatures.*** In International Mechanical Pulping Conference 2016, Jacksonville, FL, USA, pp. 249-259.

Alireza Eivazihollagh, PhD Student

Recovery of metal ions from aqueous solution

In surface and colloid engineering research group, my research interests focus on the treatment of metal ion in aqueous solution. This research allows me to pursue a fundamental understanding in solution behavior of metal ions and the techniques, for instance, ion flotation and electrochemical methods to treat metal ions in aqueous solution. This provides a solid foundation to strategically build our design in order to remove metal ion from solution and synthesize various metallic products with unique electronic, catalytic, magnetic and biomedical properties. As our main research currently centers around the novel processes to convert wood polymers to functional materials, I had this opportunity to study on the synthesis of cellulose-metal nanoparticles hybrid material. The results of our studies have been published in Materials Letters and Journal of Chemical Technology and Biotechnology.

Journal Publications

- A. Eivazihollagh, J. Bäckström, Ch. Dahlström, F. Carlsson, I. Ibrahem, B. Lindman, H. Edlund, M. Norgren, ***One-pot synthesis of cellulose-templated copper nanoparticles with antibacterial properties***, *Materials Letters* 187, 2017, 170-172.
- A. Eivazihollagh, J. Bäckström, M. Norgren, H. Edlund, ***Influences of the operational variables on electrochemical treatment of chelated Cu(II) in alkaline solutions using a membrane cell***, *Journal of Chemical Technology and Biotechnology*, DOI: 10.1002/jctb.5141.

Conference Presentations

- A. Eivazihollagh, J. Bäckström, Ch. Dahlström, F. Carlsson, I. Ibrahem, B. Lindman, H. Edlund, M. Norgren, ***One-pot synthesis***

of cellulose-templated copper nanoparticles with antibacterial properties, European Colloid and Interface Society (ECIS), Rome, Italy, 2016.

- J. Yang, C. Costa, A. Eivazihollagh, F. Carlsson, Ch. Dahlström, B. Medronho, H. Edlund, B. Lindman, M. Norgren, ***Water-based dissolution of wood cellulose and design of novel cellulose-based nanocomposite materials***, ASMCS, Materials for Tomorrow, Gothenburg, Sweden, 2016.

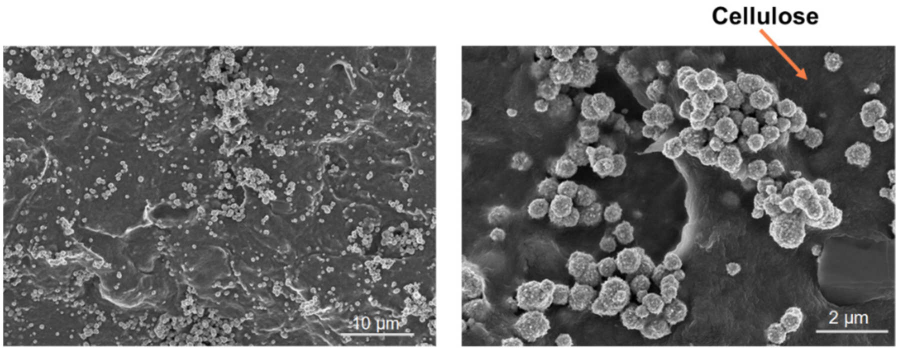


Figure. FE-SEM images of synthesized Cu NPs in a regenerated cellulose II network at two magnifications.

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