INNVENTIA

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application

CUSTOMER MAGAZINE INNVENTIA GROUP #2/2016

Special issue on nanocellulose research

Boosting business with science

Initiatives to put nano-cellulose on the market

By Anna Wiberg

Anna Wiberg
Research Manager Nanocellulose
Ask me about: Processes and applications based on nanocelluloses
Hidden talent: Renovate old houses

The nanocellulose research field is changing and development is moving increasingly fast. For a long time the focus was on reducing energy consumption during manufacturing, but the focus is now on the applications. Nanocellulose is already available as a product on the market in both Europe and North America, and is being used as a reinforcing additive in the manufacture of paper and paperboard and as a viscosity agent in various industrial applications. The question is: How can high-performance materials be manufactured using nanocellulose? It's a question of delivering the right quality at the right price, but also of having processes to manufacture at least some of all the exciting material concepts that are being developed right now at universities around the world.

"the focus is now on the applications"

At Innventia, we talk about Nanocellulose processing for various applications, which is also the title of a programme area within Innventia Research Programme 2015-2017. We are a strong team working on process development of nanocellulose-based products. In this issue of Beyond, you will meet many of the key members of our team and gain an insight into the challenges we are trying to solve. Some projects are about industrial implementation, while others are at a low TRL* and aim to develop technology platforms for the manufacture of, for instance, advanced films or fibres, all in close partnership with industry and academia. We will also explain how we work on the characterisation of nanocellulose. This requires a common language to describe the material's characteristics in order to be able to compare different types of nanocellulose and to ensure a consistent product quality. Within conducted research, we are developing our skills in using the powerful analysis techniques available at our synchrotron radiation facilities around Europe, both to get the full potential of the material, but also to understand which mechanisms are decisive when we manufacture our materials.

Although the area has taken a giant leap forward in the last ten years, we believe that the next decade will be even more exciting, a decade when we expect more progress in high-tech applications to be made. We hope that the transportable demonstration plant that is currently being built will serve as a facilitator for many of these new applications. Here at Innventia we are proud to be one of the leading players in this exciting field of innovation. ●

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* TRL = Technology Readiness Level

Forskningsområdet nanocellulosa är i förändring och utvecklingen går allt snabbare. Efter att under lång tid ha fokuserat på att sänka energiförbrukningen vid tillverkning, ligger fokus idag på tillämpningarna. Nanocellulosa används redan idag som styrketillsats vid tillverkning av papper och kartong och som konsistensgivare i olika industriella applikationer. Frågan är: Hur högpresterande material kan man tillverka av nanocellulosa? På Innventia pratar vi om *Nanocellulose processing for various applications*. I detta nummer kan du läsa om några pågående aktiviteter och utmaningar inom t ex karaktärisering, teknologiutveckling och förståelse för att utnyttja materialets fulla potential.

New methods for characterisation

With the increase in applications for nanocellulose, new and better methods are required to characterise the properties of the material. Different properties are important in different applications. Ali Naderi at Innventia is developing new methods for characterisation.

Nanofibrillated cellulose, CNF, is a form of nanocellulose that was first manufactured over 30 years ago.

"The general perception is that products containing nanofibrillated cellulose only consist of nanoparticles, but the fact is that CNF is a very heterogeneous and complex system that is difficult to study," says Ali Naderi, a researcher at Innventia who is working on characterising various CNF systems, among other things.

In recent years nanofibrillated cellulose has started to be used in various applications, such as a strength additive for making paper and cardboard stronger, in skincare and in nappies. Other applications are in the pipeline.

When it comes to its applications, it is important to note that there are various grades of CNF that have very different properties. In order to choose the right material for a specific use, you need to be able to distinguish and characterise the different grades of CNF. Examples of methods used today include rheological measurements of CNF suspensions, measuring the tensile strength of films based on CNF and investigation of the barrier properties of the films.

"In order to be able to develop new CNF-based materials, we need, for example, to understand how they interact with other materials and be able to characterise nanofibrillated cellulose in various compositions. For example, it is important to measure how well CNF is mixed in composites and quantify the strength of the interaction of the nanoparticles with other components of the composite. That would require more advanced characterisation methods than we currently use," says Ali.

One example of such methods are those based on X-ray scattering. Using these, you can look at the microstructures of the materials, among other things.

That is why Ali Naderi is interested in the method. At the end of July he travels to Stony Brook University in the USA to spend five months learning how to characterise materials using X-ray scattering.

"I want to acquire the knowledge and use it in various research contexts at Innventia," he says.

The new knowledge can help to increase the use of nanocellulose.

"I have been given the opportunity to learn an analysis method that may be of huge value to Innventia's research activities. We will be able to help different players to use nanofibrillated cellulose in their applications. It is important for Sweden, and it is important for the environment that we can increase the use of bio-based materials," says Ali. ●

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Ali Naderi demonstrating some of the Innventia's facilities for NFC characterisation.

Ali Naderi awarded the Skills Prize

On 12 April, Ali Naderi was awarded this year's Kompetensutvecklingspris (Skills Prize) from the Gunnar Sundblad Research Foundation by His Majesty King Carl XVI Gustaf of Sweden on 12 April during Skogsnäringsveckan (Forestry Week) in Stockholm.

The prize of SEK 500,000 is for development of methods for studies of nanocellulose-based materials. This prize makes it possible for Ali Naderi to spend five months at Stony Brook University in New York. Along with Professor Benjamin S. Hsiao, an authority in employing X-ray scattering for the characterising of materials, develop methodologies for the study of CNF-based systems. It is envisaged that the methodologies will lead to a better understanding of the modes of interaction of CNF with varying materials.

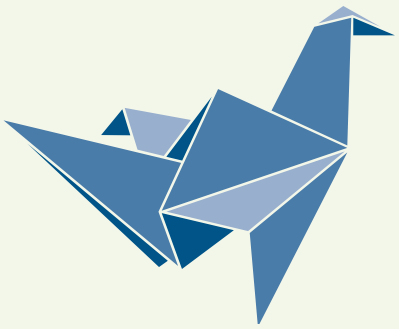
"It's really exciting! I have been given the opportunity to learn an analysis method that may be of huge value to Innventia's research activities," says Ali Naderi. ●

Nanofibrillär cellulosa, CNF, har på senare år börjat användas i olika tillämpningar, exempelvis i papper för att göra det starkare, i hudvård och i blöjor. Andra tillämpningar är på ingång. För att kunna utveckla nya CNF-baserade material är det viktigt att förstå den nanofibrillära cellulosans växelverkan med olika material och kunna karaktärisera den i olika blandningar. För detta krävs nya avancerade metoder. I slutet av juli åker Ali Naderi till Stony Brook University i USA för att under fem månader lära sig hur man kan karaktärisera material med hjälp av röntgenspridning, en metod som gör det möjligt att bland annat titta på mikrostrukturer hos material.

Innventia Research Programme

NanoVisc is one of the application oriented projects within *Nanocellulose processing for various applications in the* current Innventia Research Programme 2015-2017. Some important characteristics for the Programme Areas are that they:

- consist of several pre-competitive themes, thereby developing new knowledge or new combinations of knowledge to be used for new technical solutions and applications in
- one or several application oriented research projects, that can give results to be developed fur ther to industrial reality together with customers through client projects.



The Paper and Fibre Research Institute, PFI, in Trondheim is involved in a number of nanocellulose projects.

The largest is NORCEL, a national project for research into and development of nanocellulose for use in paper and cardboard, within the oil industry, and for tissue reconstruction, where the nanocellulose can offer a support for cells to grow on.

Another project is developing an additional application within the field of medical engineering, for wound healing.

Other projects are exploring, for instance, how to use nanocellulose to force the oil out of porous rock types on the ocean floor. At the moment, salt water is injected to increase the pressure of the oil, but this method extracts less than half of the available oil. The rest remains in the rock. PFI researchers are testing whether more can be extracted using nanocellulose.

The researchers are also investigating whether composite membranes containing nanocellulose can be used to separate CO_2 from flue gases and biogas. ●

MORE INFO: www.pfi.no

Partnership for increased viscosity in foods and cement

Nanocellulose is already used to increase viscosity in some paints, for example. Now researchers at PFI, in a broad partnership with academia and the business sector, are investigating if the material can be used as a viscosity enhancer in a greater number of products.

The Paper and Fibre Research Institute (PFI) in Trondheim, Norway, is studying whether nanocellulose could be used to increase the viscosity of foods and improve the properties of cement.

"We want to learn more about various types of nanocelluloses for use as a viscosity enhancer in food and skin care products and if, for instance, it can increase the strength of cement," explains Kristin Syverud, who is the senior researcher and responsible for the focus area of nanocellulose at PFI.

The PFI researchers are working on a number of different types of nanocelluloses and are investigating the effects of using nanocelluloses as additives and if and how other additives influence such effects. They are also looking more closely at what happens if the material is used to stabilise emulsions.

"The end product will be used in food and cement, among other things. In order to get there, we need a significant basic understanding of how nanocelluloses act as viscosity enhancers and emulsifiers. We want to learn how they function in systems with many other substances. They are affected by salt, acid, grease, etc., found in the different end products. We want to check that we get the required effects," says Kristin.

The work is being undertaken in a broad partnership involving research institutes, universities and companies from several different industries. PFI is a subsidiary of Innventia. A number of research institutes are cooperating in the project. Both PFI and Innventia manufacture various types of nanocelluloses that are being used in the investigations.

Another five parties are also taking part. They are the Norwegian University of Science and Technology (NTNU) in Trondheim, pulp manufacturers Stora Enso, Mercer and Borregaard, cement manufacturer Norcem and food producer Mills.

The NanoVisc project within Innventia Research Programme 2015-2017 is lead by Fredrik Wernersson Brodin, PFI. It is financed by the Research Council of Norway and the companies that are taking part, such as Norway's Borregaard.

"We create networks and gain access to different skills than those found in our own company and get updated on what's happening in research institutes and academia. We are hoping for new applications that need our product," says Hans Henrik Øvrebø, who is in charge of technology development at Borregaard.

"The companies also contribute with expertise, Mills for food and Norcem for cement. All companies are involved in discussions on various activities," says Kristin Syverud. ●

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Kristin Syverud is senior researcher and responsible for the focus area of nanocellulose at PFI.

PFI, Innventias norska dotterbolag driver en rad nanocellulosa-projekt. Det största är NORCEL, en nationell FoU-satsning för användning i papper och kartong, inom oljeindustrin, och för vävnadsrekonstruktion, där nanocellulosan kan utgöra ett stöd för celler att växa på.

I projektet NanoVisc samarbetar PFI och Innventia med akademi och företag för att undersöka om nanocellulosa kan användas som viskositetshöjare livsmedel och betong. För detta behövs grundläggande förståelse för hur nanocellulosa verkar som viskositetshöjare och som emulsionsmedel samt hur den fungerar i system med många andra ämnen.

Nanocellulose as a barrier material

The recently completed EU project Nanobarrier has increased knowledge of nanocellulose as a barrier material in food packaging solutions. The insights gained will now be used in other projects.

The goal of this large EU project was to develop five prototypes of biobased and biodegradable food packaging using barrier materials based on nanocellulose in various forms.

"The aim is to reduce the use of materials that generate carbon dioxide emissions and to save resources, while we extend the shelf life of food and reduce food waste," says Christian Aulin, a researcher at Innventia and project manager for the institute's contribution to the project.

Innventia's role was to produce a material in three layers that can be used in tray packaging for meat. The different layers were to be made from nanocellulose and the biopolymer PLA, polylactic acid, which, like nanocellulose, is biodegradable.

Initially, the researchers created a film of nanocellulose, approximately 10 x 10 centimetres in size. They then optimised and scaled up the manufacturing process. The properties of the film were then improved with various types of additives.

"We have used various types of nanosized clay particles to improve the barrier properties, as well as various plasticizers to improve the flexibility of the film."

The three-layer material was manufactured by coating a film of nanocellulose with PLA on both sides. Polylactic acid can be vacuum thermoformed, which makes it easier to then shape the tray packaging without the nanocellulose breaking. It also functions as protection for the layer of nanocellulose in the middle.

Christian Aulin is very pleased with the results.

"We have been very successful. The nanocellulose film has been given a ten times better oxygen barrier. And the tray's multi-layer material has a better oxygen barrier than the ordinary commercial product we compared it with," he says.

The Nanobarrier research and innovation project had a budget of SEK 100 million and partners from nine European countries. In total there were 15 participants, including pulp and paper manufacturer SCA, biorefinery company Borregaard, packaging manufacturers, universities and research institutes. The project started during the EU Commission's previous framework project, FP7. It lasted four years and ended in March this year.

"We have gained knowledge that we can use in other cooperation projects," says Christian.

A brand new project financed by the Eureka international cooperation network will be investigating, for instance, if nanocellulose can be used in barrier material for displays for such things as mobile phones, laptops and solar cells. Researchers from Sweden and Switzerland, as well as several companies, participated in the project. ●

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The Nanobarrier consortium was led by the Norwegian research institute SINTEF.

EU-projektet Nanobarrier hade som mål att ta fram fem prototyper av biobaserade och biologiskt nedbrytbara livsmedelsförpackningar, med barriärmaterial baserade på nanocellulosa i olika former. Innventias roll var att ta fram ett material i tre skikt som kan användas i en trågförpackning för kött. De olika skikten skulle vara av nanocellulosa och biopolymeren PLA, polymjölksyra, som liksom nanocellulosan är nedbrytbar. Resultatet blev mycket bra. Själva nanocellulosan har fått en tio gånger bättre syrgasbarriär. Tråget i flerskiktsmaterial har bättre syrgasbarriär jämfört med en vanlig kommersiell produkt. I ett nystartat projekt undersöks om nanocellulosa kan användas i barriärmaterial för displayer i t.ex. mobiltelefoner.

Interdisciplinary science lifts the field

Eva Ålander at Innventia's pilot plant where nanocellulose is produced for R&D on various applications.

Innventia is involved in a broad interdisciplinary project in cooperation with three universities and two companies to produce new composites using nanocellulose. They are also investigating in parallel with this whether there are any health or environmental effects.

The aim of the Forest for Future project is to produce composites based on nanocellulose. Others are also working on the same problem. But what is special about this project is that the researchers are integrating environmental and health aspects as early as the material development stage.

"Weaving together all the different aspects at an early stage is an unusual approach," says Ulrica Edlund, a researcher at KTH Royal Institute of Technology and project manager.

She describes the approach using a concept borrowed from mathematics, iteration. That's another word for repetition and it involves fine-tuning a process until the required results are achieved.

Innventia is manufacturing the nanocellulose for this project. KTH modifies its surface and produces test composites. In parallel, researchers at the universities in Uppsala and Stockholm analyse the materials with regard to toxicology and environmental impact, while Innventia and KTH analyse the structure and properties. Once these tests are complete, the process will start over.

The materials being used as a starting point are nanocellulose and a plastic matrix.

"The nanocellulose is originally hydrophilic and the material in the plastic matrix is hydrophobic. This does not provide a good interaction," says Eva Ålander. Eva is a researcher at Innventia and also a project manager.

The nanocellulose is modified, therefore, to make it more hydrophobic and to enable it to mix better with the composite's matrix. The KTH researchers do this by changing the surface chemistry.

"Following modifications, the nanocellulose is checked for environmental impact and toxicological effect," says Ulrica.

Researchers at Stockholm University are studying how crustaceans are affected if they are exposed to the materials. The preliminary results show no toxicity. It even appears as if the crustaceans eat the nanocellulose. The Uppsala researchers are examining how human cells react to nanocellulose exposure.

"You have to respect the idea that there is a risk that nanocellulose is interacting with tissue in unwanted ways. The dimensions are minute and can involve a difference compared to standard cellulose. The nanocellulose can get into, and interact with, tissues, as it has such a large surface area. We want to help to investigate that," says Ulrica.

The project started just over 18 months ago and is now approaching its first iteration.

"The first cycle takes time, as new methods and working practices are being developed," says Eva Ålander.

Other participants in the project, which lasts for four years and is supported by Formas, include the companies Stora Enso and Biobag, which are helping to ensure the materials developed also have an industrial relevance. Industry organisation SwedNanoTech is in charge of communication. Eva and Ulrica pay tribute to the cooperation.

"It would have been impossible to reach the goal without cooperation. Everyone is contributing a piece to the puzzle. Without the universities in Uppsala and Stockholm, we would lose the safety aspect," says Ulrica.

Eva adds:

"Interdisciplinary science lifts the field. It is a fantastic collaboration, with huge potential for successfully producing a new packaging material based on nanocellulose," she says. ●

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Forest for Future är ett brett tvärvetenskapligt projekt i samarbete med tre universitet och två företag. Målet är att framställa kompositer baserade på nanocellulosa. Det speciella med detta projekt är att forskarna redan vid materialutvecklingen integrerar miljö- och hälsoaspekter. Arbetssättet väver in alla aspekter samtidigt i en iterativ process som går ut på att upprepa och finjustera tills man når ett önskat resultat. Materialen man utgår ifrån är nanocellulosa och en plastmatris. För att dessa ska kunna blandas modifieras nanocellulosan för att bli mer hydrofob. Efter modifieringarna kontrolleras nanocellulosan avseende miljöpåverkan och toxikologisk effekt.

Concerted efforts for energy storage papers

Energy supplied at the wrong time costs a lot and has increased the demand of solid, cheap and sustainable energy storage modules. This is a challenge that is attracting many researchers.

On 20-21 April, the Energy Storage Papers 2016 symposium was held at Innventia where the latest findings from this highly topical research field were presented and discussed together with the industry. The symposium was initiated by the MODULIT project, the aim of which is to demonstrate manufacturing of complete energy storage modules in a roll-to-roll process. Another project discussed at the symposium was Power Papers which involves a paper with a unique ability to store electricity. The material consists of nanocellulose and conductive polymers. A continuation of this project has now been launched with a focus here is on production methods. Production of Power Papers, lead by Innventia's Karl Håkansson, aimes to demonstrate scalability in terms of manufacturing supercapacitors in paper-like processes. ●

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Mats Sandberg coordinated and Hjalmar Granberg hosted the first Energy Storage Papers Symposium at Innventia 20-21 April, 2016. Here surrounded by Gero Decher and Lars Wågberg.

New organisation at Innventia

On 4 April, 2016, Innventia launched a new organisation. The mobilisation is being undertaken so that we are better equipped for the opportunities and challenges that we will be encountering in the bioeconomy of the future.

The operation is being organised in two new business areas, Biorefinery & Biobased Materials under the direction of Catharina Ottestam and Papermaking & Packaging, under Marco Lucisano. At the same time a function is being established with specific responsibility for bioeconomic strategy through Peter Axegård.

"The new organisation will give us better opportunities to meet the challenges of the industry. It also harmonises with the strategies for a stronger Swedish institute sector through RISE Research Institutes of Sweden," says Birgitta Sundblad, President of Innventia. ●

Peter Axegård, Catharina Ottestam and Marco Lucisano.

IMAGINE a future in which resources from forests are used to create an array of products – everything from textiles and vehicle parts to cosmetics and prosthetics. This leads to the forest becoming a more important resource in the production of materials and products for which we currently use oil, plastic, glass or metals.

What do you think about this scenario?

We asked this and many more questions to people in five countries around the globe!

Welcome to the release of our third Innventia Global Outlook Report: A Cellulose-Based Society 24 May at the International Biorefinery Week at Stockholm International Fairs.

www.innventia.com/cbs-release2016

COMING EVENTS

JUNE

13-16	TAPPI International Conference on Nanotechnology for Renewable Materials
16-17	Residues of Food Contact Materials in Food
28-30	Zellcheming
28-30	14th European Workshop on Lignocellulosics and Pulp (EWLP)

SEPTEMBER

27-28 Innventia Days 2016

OCTOBER

4-6	TAPPI Advanced Coating Symposium
4-7	TokyoPack
19-20	PFI conference: Recent advances in cellulose nanotechnology research

New Board of Directors

From 1 April, Innventia is 100% owned by the Swedish Government through RISE Research Institutes of Sweden AB.

A new Board of Directors was appointed during Innventia's General Meeting on 2 May, 2016. The new board is chaired by Olof Sandén, RISE, and the other members are Mikael Hannus, Stora Enso, Susanne Ljungqvist, RISE and Birgitta Sundblad who remains as President of Innventia. Employee representatives are Ewa Lie (SAK) and Pierre Ljungquist (Unionen). ●

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Let us know by sending an e-mail to info@innventia.com.

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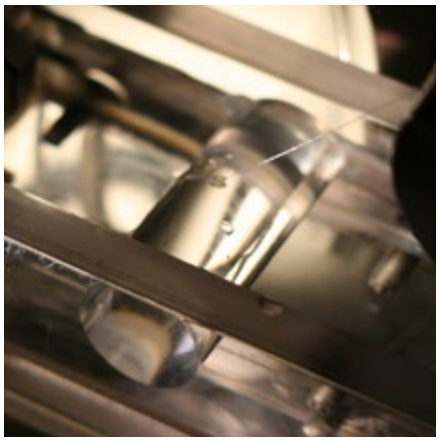
Like a spider silk

Researchers at KTH Royal Institute of Technology and at Innventia have been working in partnership to develop a method for manufacturing thin, strong nanocellulose thread. The material is recyclable and biodegradable and could, for example, replace cotton in fabrics or fibreglass for reinforcement purposes. Innventia researcher Karl Håkansson will now scale up the process.



Researchers at KTH Royal Institute of Technology and at Innventia have developed a new method for spinning nanocellulose into a thin, strong thread. They have released the tiny fibrils in the wood fibre and have managed to align them in the same direction, then joining them together again to form a continuous thread.

The results were met with great interest when they were published in the scientific journal Nature Communications.

"We demonstrated for the first time that it was possible to recombine the fibrils and that it is possible to create threads with a good arrangement of fibrils," says Fredrik Lundell, a researcher at KTH.

The thread was manufactured in a flow cell in which two streams of water rapidly flow from two directions towards a third flow that contains the nanofibrils. That makes the fibrils arrange themselves in the same direction. Salt is added to get them to lock in that position. Positive ions in the salt then bind to the negative charges on the fibrils, which are neutralised and get close to one another. The result is that a gel is formed that becomes a long thread of nanofibrils in the water flow.

"We have been able to demonstrate that this process can function continuously," explains Karl Håkansson, whose thesis at KTH/Wallenberg Wood Science Center forms the basis for the work.

He is now a researcher at Innventia, where he is continuing the work of scaling up the process.

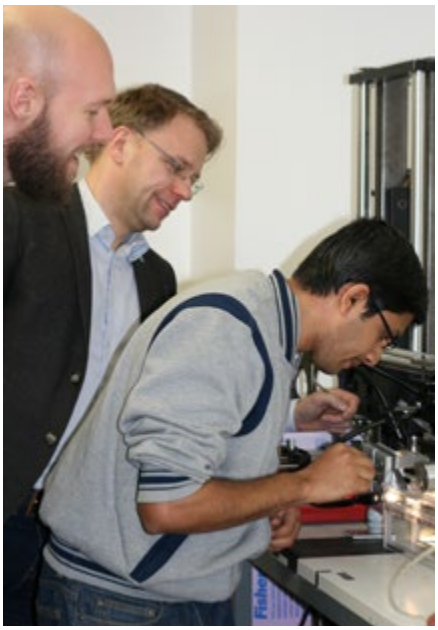
"The goal is to be able to manufacture the thread, roll it up and dry it. There is 99.7 per cent water in the process to keep the fibrils apart in the flow. The thread needs to be dried, and that is a challenge. Part of our work is to understand the drying," says Karl.

KTH researchers will investigate in detail what happens during the process. One goal is to increase knowledge of how the properties of the thread can be controlled. They already know that the geometry, such as the angle at which the channels are brought together, is important to the orientation of the fibres. This in turn determines the properties of the thread.

"They are learning the dynamics at nano level. We apply it to the process. They optimise the process for manufacture; we scale it up. They are involved in cutting-edge research and we know what the industry requires and can help manage the research so that it is more industry-relevant," says Karl.

The partnership is well developed and there is benefit on both sides.

"Innventia works on research-based ideas we come up with, and we get help understanding what aspects are of practical use and most relevant to the needs of the industry. When Innventia develops the continuous process, we expect flow problems that we can study more thoroughly," says Fredrik Lundell. ●



Karl Håkansson and Fredrik Lundell together with doctoral student Krishne Gowda.V.

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En ny metod att spinna nanocellulosa till en tunn och stark tråd har utvecklats av forskare vid Innventia och KTH/WWSC. De har frigjort de små fibrillerna i träfibern, lyckats ordna dem i samma riktning och sedan fogat ihop dem igen till en lång tråd. Resultaten möttes av stort intresse när de publicerades i den vetenskapliga tidskriften Nature Communications. Tråden tillverkas i en flödescell där två strömmar av vatten snabbt flödar från två håll mot en tredje ström, som innehåller nanofibrillerna. Det gör att fibrillerna ordnar sig i samma riktning. Genom att tillsätta koksalt binds dess positiva joner till negativa laddningar på fibrillerna som neutraliseras och kommer nära varandra. Resultatet är att det bildas en gel, som i vattenflödet blir en lång tunn tråd av nanofibriller.

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