SUNPAP Newsletter 6 19.11.2012
Scaling-up nanoparticles in modern papermaking

Welcome to our sixth and final SUNPAP newsletter. The demonstration phase of the SUNPAP project was completed and the results were disseminated in the final conference in Italy. VTT coordinated this large-scale project aiming to scale up novel applications based on nano fibrillated cellulose in paper and board value chains. The research done in cooperation with several research partners has shown great potential for the use of NFC as an additive in paper making.

The final conference of the SUNPAP project was held on 19-20 of June. Over eighty participants attended the two-day event in Milan, Italy. The main focus in the conference was on pilot-scale work and demonstrations carried out in the project. The programme also attracted industrial people and almost half of the audience members were representatives from the industry. The participants were from southern Europe, central Europe, and northern Europe, with almost one third from each area. The conference was also attended by non-European industrial representatives from Japan and Brazil. The programme and presented materials can be found at http://sunpap.vtt.fi/finalconference2012.htm.

Nano fibrillated cellulose (NFC) is one of the most promising nanomaterials for wide-variety applications. However, when the project was started, NFC was prepared and applied in papermaking mainly on a lab scale. The target of the project was first to scale up the NFC production processes, and then to adapt this nanomaterial for modern papermaking processes via the demonstrated pilot lines. The final goal of the SUNPAP project was to enable the introduction of NFC-based processes to various types of applications in the papermaking value chain (Figure 1), and the main aims were to develop and demonstrate:

1. High performance products and environmentally friendly NFC-enabled production processes, demonstrated for graphical papers and packaging boards
2. Functional products and innovative processes enabled by NFC with active functionalities, demonstrated for papers and packaging materials
3. High added value fibre-based products with highly specific properties made possible by NFC, demonstrated for fibre-based filters and other selected innovative materials.

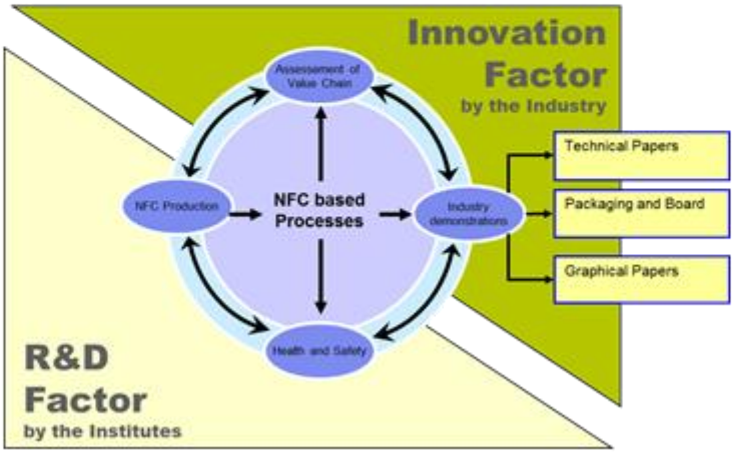

Figure 1. The targeted applications of the project in the papermaking value chain.

The energy consumption of NFC production is high and needs to be reduced. The high potential could be seen through a combination of the mechanical refining and enzymatic pre-treatment before homogenization, or through pre-treating the pulp fibres with oxidative chemicals without intensive refining. Based on these findings, a new pilot line with high pressure homogenizers was built at CTP in parallel to this project, and the semi-pilot-scale rotor-/stator-machine at PTS was completely re-engineered in order to produce NFCs for other project partners. Three different NFCs (from coarse aggregates of microfibrils to fine individual nanofibrils) were produced on a large scale and these were used for the production of the selected demonstrators. The main conclusion of the material cost calculations was that the chemical costs of the chemically pre-treated NFCs out-weighed the higher electricity and capital costs of the enzymatically pre-treated NFC. The results of the NFC qualities produced on a large scale are shown in Figure 2.

1. NFC-CTP = enzymatically pre-treated pulp combined with mechanical refining followed by high pressure homogenizer
2. NFC-TE/CTP = TEMPO-oxidized pre-treated pulp followed by high pressure homogenizer
3. NFC-TE/PTS = TEMPO-oxidized pre-treated pulp followed by rotor-/stator-machine

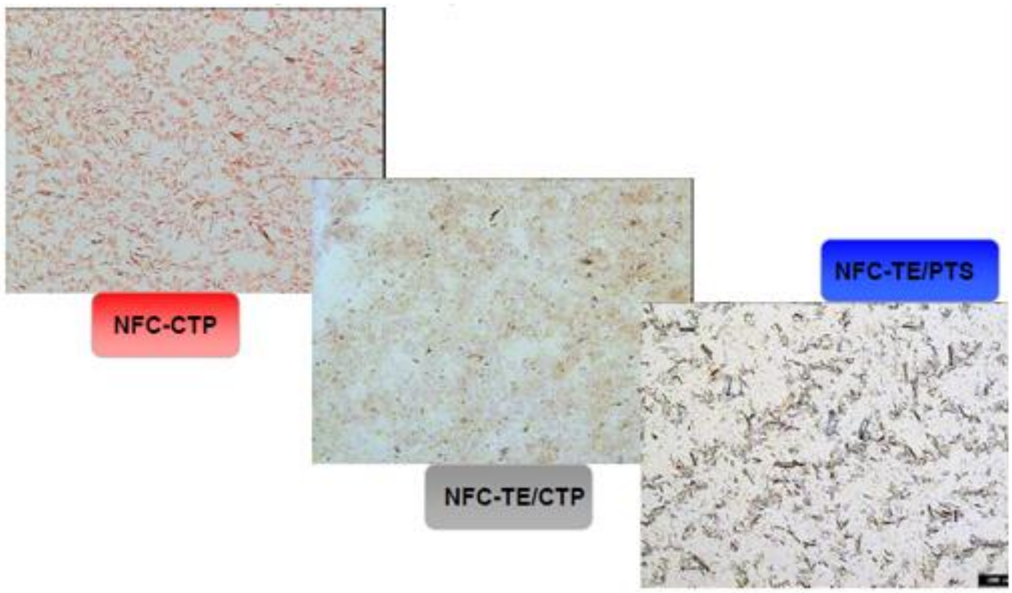

Figure 2. Light microscopy pictures of NFC-CTP, NFC-TE/CTP, and NFC-TE/PTS

NFC does not only offer possibilities to improve current products on the market, but it makes it possible to develop completely new types of value added products for niche markets. In conventional pigment coating trials, no major benefits were gained by replacing latex with NFC in pigment coating colour. Increased drying demand due to the low solids will limit the used amounts. However, there are some possibilities to use NFC as a rheology modifier or to improve some critical product properties. For example, in the case of coated inkjet photo paper, the production speed is normally limited by cracking during drying. The use of small amounts of NFC in the curtain coating had a clear positive impact on both inkjet paper quality and production efficiency (higher speeds can be used). As the final demonstrator for the NFC use in inkjet coating, a photograph of the SUNPAP project team was printed on photo paper containing NFC and handed out during the final conference in Milan (Figure 3).

Figure 3. A photograph of the SUNPAP project team was used as one demonstrator. The photo paper contains 0.06% NFC in the coating layer.

NFC can also give good oxygen and grease barrier properties in multilayer barrier products and can replace partly non-renewable materials in dispersion coatings. The drying quality of the dispersion coating layer (polyvinyl alcohol) was improved with the use of NFC. As the second-layer barrier, latex or extrusion coating with PE improved further barrier properties when coated on top of the polyvinyl alcohol and NFC layer. The boards from the final coating trials were then converted into small packages. These small board packages are shown in Figure 4.


Figure 4. End-use barrier packaging demonstrator

Novel products with active properties are possible with functionalised NFCs (with inorganic particles). Very high antibacterial activity of papers could be achieved with thin layers of NFC-TiO2 and/or ZnO. NFC-ZnO and NFC-TiO2 nano composites were prepared by physical adsorption, by mixing NFC and inorganic nanoparticle suspensions. NFC-TiO2 also has significant activity for the oxidation of NO and NOx with low coat weights. Thin layers could be applied on the surface by using a novel foam-coating applicator installed by VTT in the pilot coating machine (Figure 5). The use of air instead of water makes the application of viscous cellulose nanofibril solutions possible.

Figure 5. a) NFC in feeding tank (left), b) foamed NFC before application unit (middle), and c) VTT´s narrow slot type applicator in a large-scale pilot coating machine (right).

Sustainability assessment showed that the changes in environmental impacts in the pigment coating case were negligible, due to very small amounts used. However, for the bulk structures, the trend was very positive, and radically lower environmental impacts were achieved when the use of NFC enabled, due to the higher strength, a lower basis weight. NFC containing aggregates gave, in most cases, results as good as those from fine NFC. The presence of NFC in demonstrators did not induce large changes in recycling/de-inking. The tested coated board products, including NFC in the coating layer, passed the different biodegradability tests, and their compostability was confirmed. NFCs are viscous gel type materials and are used mainly in wet form. The toxicological studies *in vitro* and *in vivo* did not indicate any major concerns, except for the occupational inhalatory exposure, which, however, can be managed by standard protective measures. NFCs seem to be biodegradable and non-toxic, and no big changes in the safety or recycling of products containing NFC are expected in the future.

As an overall conclusion, it seems evident that nanocellulose will be added in the future not only in special products for niche markets, but also widely in different kinds of packaging paper and board products with high production volumes. More product development work in the area of using NFC to increase strength in bulk structures or to create novel functionalities with surface treatments is still needed. The important impact of the SUNPAP project on the scientific community was the numerous publications and dissemination activities that have increased the knowledge of the possibilities and challenges in this area. The development of the research facilities carried out in the project or in parallel projects will improve the possibilities to continue the work in the future.

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Innovhub - Stazione Sperimentale per L'Industria, Italy
Grenoble INP Pagora, France
Finnish Institute of Occupational Health, Finland

Universities:
Universidade de Aveiro, Portugal
Karlstad University, Sweden
TUT Foundation, Finland
Aalto University Foundation, Finland

SME partners:
Cavitron vom Hagen & Funke GmbH, Germany
Hansa Industrie-Mixer GmbH & CO. KG, Germany
BioSafe - Special Laboratory Services Oy, Finland
NanoSight Ltd, U.K.
J. Zimmer Maschinenbau GmbH, Austria

Industrial partners:
Colorobbia SPA, Italy
Schoeller Technocell GmbH & Co KG, Germany
Pöyry Management Consulting Oy, Finland
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