2018- Cellulose Nanomaterials Production Update
Summer, 2018

Production Summary

Activities in the production of Cellulose Nanomaterials (CN) have continued to accelerate since our last update in December, 2015. To help track this progress the Nano Division has teamed up with Jack Miller of Biobased Markets to summarize the state of the industry. Information presented here is extracted from reports produced by Jack Miller and updated. Periodic updates will be made to this website so that the information remains current.

Jack Miller's Bio:

Jack Miller is Principal Consultant, Market-Intell LLC, which he founded in 2005 and re-branded as Biobased Markets in 2018. Jack is also an Associate Consultant with RISI and a member of the Advisory Board of Sweetwater Energy, a biorefinery company. Jack served as Business Development Consultant with CelluForce, Inc., from 2011 to 2013, and was Consulting Manager, Global Nanocellulose Sales, American Process, Inc., in 2014 and 2015. Prior to 2005 Jack enjoyed a long career in the pulp and paper industry.

Jack is the author of *Nanocellulose Challenges and Opportunities: End User Perspectives,* published by TAPPI in 2018 and *Nanocellulose Producers, Products and Applications, A Guide for End Users*, published by TAPPI in 2017. He is also the author of *Nanocellulose: Technology, Applications, and Markets,* published by RISI in 2014, and *Lignin: Technology, Applications, and Markets* published by RISI in 2017.

Jack is currently working on a new study of markets for nanocellulose in packaging, which will be available from RISI in the next few months.

Cellulose Nanocrystals (CNCs)

Recent Updates

Sweetwater Energy is a new addition to the list of CNC producers. Sweetwater is a biorefinery that that has patented processes for low cost production of a full range of high quality biorefinery products including pure lignin, activated carbon, C5/C6 sugars, and most notably, microcrystalline cellulose (MCC) which can readily be converted to cellulose nanocrystals (CNC). Sweetwater operates a pilot plant in Rochester NY and has begun construction of a commercial scale facility in Estonia.

Klabin, another new addition to the list, acquired an equity position in **Melodea** in February, 2018**.** Melodea's 35 tpy CNC plant in Örnsköldsvik, Sweden is in the final stages of commissioning and is scheduled to start commercial production before the end of 2018.

CelluForce reports that its upgrade at the Windsor QC facility will be completed in autumn, 2018, and the plant will resume operations then.

American Process reports joint development efforts with Birla Carbon, MYBiomass, and Will & Co. B.V. and P.R.G. B.V.

Blue Goose Biorefineries announced a license agreement with Purdue University to commercialize Purdue's technology for CNC reinforced concrete.

Production of CNC by acid hydrolysis is well known, but in recent years biorefineries such as American Process, Sweetwater Energy, and Blue Goose have begun producing CNC by other means. 2018 CNC capacity is listed below.

CNC Capacity 2018
(tonnes per year, dry basis)

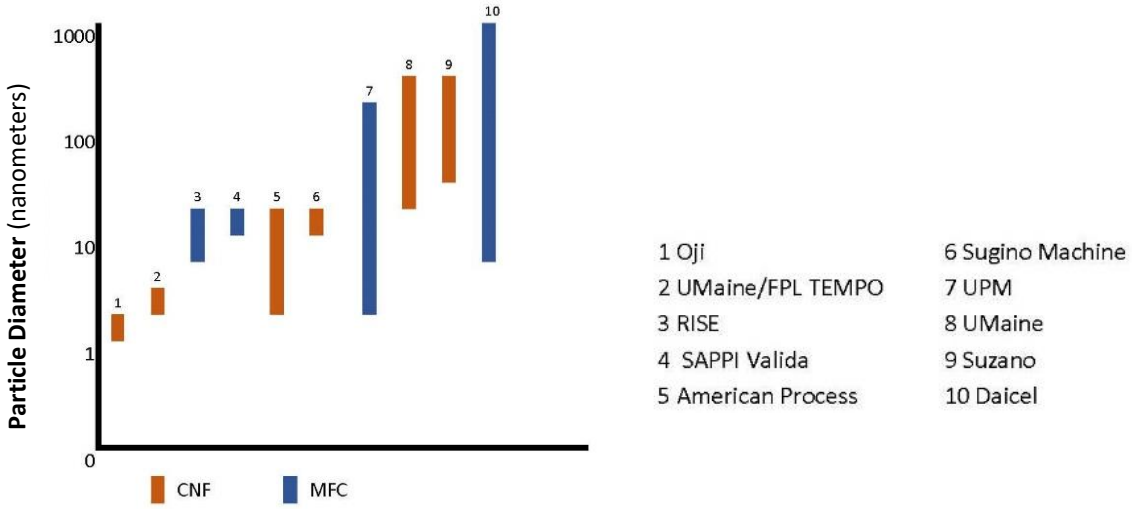
Producer	Process	Capacity
CelluForce, Canada	sulfuric acid hydrolysis	260
American Process, USA	SO_2 fractionation	130
Melodea, Sweden	sulfuric acid hydrolysis	35
Alberta Innovates, Canada	acid hydrolysis	5
U.S. Forest Products Lab, USA	sulfuric acid hydrolysis	3
Blue Goose Biorefineries, Canada	catalytic conversion	2
FPInnovations, Canada	sulfuric acid hydrolysis	Pilot
Hangzhou Yeuha Technology Co., China	Proprietary	Pilot
Sweetwater Energy, USA	Reactive extrusion	Pilot
Tianjin Haojia Cellulose Co., Ltd., China	Modified and unmodified	Pilot

Source: *Nanocellulose: Producers, Products, and Applications, A Guide for End Users,* TAPPI, 2017. Updated, Biobased Markets, Sept. 2018.

Cellulose Nanofibrils (CNFs) and Microfibrillated Cellulose (MFC)

The terms cellulose nanofibrils and microfibrillated cellulose are being used interchangeably. There is considerable overlap in specifications, and, as the figure below shows, many of these materials contain a mix of nano-scale and micro-scale particles. Some producers prefer to call their material "nano" because it sounds more advanced, while others prefer to call it "micro" because of perceptions about environment, health, and safety issues. Both CNF and MFC are generally included in discussions of cellulose nanomaterials. Here we will use the terminology the producers use.

CNF and MFC Particle Diameters



Source: *Nanocellulose: Producers, Products, and Applications, A Guide for End Users,* TAPPI, 2017

Recent Updates with CNF and MFC

GL&V and FiberLean are actively marketing technologies and equipment for mills to produce these materials, and FiberLean MFC capacity is included here. However, sources suggest that the largest volumes are in captive paper and paperboard markets, i.e., mills quietly producing MFC or CNF and using it in their own products. Although most of these are not identified, one estimate suggests that this volume runs to tens of thousands of tonnes of MFC/CNF.

Turners Falls Paper, the first commercial installation of the **GL&V FibreFine** technology, closed in April 2017 due to conditions in paper markets. GL&V reports that there have been numerous trials at various mills, with several possible new installations, but details remain confidential.

FiberLean had capacity for 8,000 tonnes of MFC, approximately 40,000 tonnes of FiberLean MFC Composite, at the beginning of 2018. In June, 2018, a new FiberLean MFC installation started up at the

NorPaper mill in Nantes, France. The plant is expected to produce a minimum of 800 tonnes per year of MFC.

Borregaard Exilva is reported to be the first commercial scale MFC. Following successful trials with the RISE Innventia mobile pilot plant, full scale testing of packaging products with Exilva is now underway with **BillerudKorsnäs**.

American Process announced the launch of its GreenBox++® technology for chemical-free production of corrugating medium. In 2016 API installed a demonstration line at its Thomaston, Georgia biorefinery for production of up to 0.5 tons per day of high lignin content cellulose nanofibrils, GB-Fibrils™, using the GreenBox front-end technology, and has reported collaborations with containerboard mills in the U.S., Canada, and Malaysia.[i]

The **Kyoto University Research Institute for Sustainable Humanosphere** (RISH) has established a pilot plant with a capacity of one tonne per year of thermoplastic resins with 10 wt.% CNF. Seiko PMC constructed a pilot plant based on this Kyoto process in 2013, and Nippon Paper did so in 2017.

Stora Enso had a test market with 100 million Elopak packages with MFC-containing liquid packaging board. Imatra is reported as a pilot plant, but "Stora Enso invested EUR 9 million in new MFC production at Imatra, Ingerois and Fors mills. The new capacity corresponds to 500,000 tonnes of board made with MFC after a ramp-up period of 3–5 years."[ii] At 3% to 5% MFC, that would be 6,000 to 10,000 tonnes of MFC capacity. Contacts at Stora Enso have not responded to requests for current updated capacity information.

CNF and MFC capacity are listed below.

CNF Capacity 2018

(tonnes per year, dry basis)

Producer	Process	Capacity
Nippon Paper, Japan	TEMPO, carboxylated	560
University of Maine, U.S.	Mechanical	260
American Process, U.S.	SO_2 fractionation	130
CelluComp, UK	chemical pretreatment	100
Chuetsu Pulp and Paper, Japan	aqueous counter collision	100
Oji Paper, Japan	phosphate esterification	40
Sugino Machine, Japan	oblique collision	26
Seiko PMC, Japan	modified hydrophobic	24
SAPPI, Netherlands	Chemical	5
VTT, Finland	chemical, enzymatic	5
Tianjin Haojia Cellulose Co., Ltd, China	TEMPO, carboxylated	3
Dai-ichi Kyogo (DKS), Japan	TEMPO	1
U.S. Forest Products Lab, U.S.	TEMPO, mechanical	<1

Source: *Nanocellulose: Producers, Products, and Applications, A Guide for End Users,* TAPPI, 2017. Updated, Biobased Markets, Sept. 2018.

MFC Capacity 2018

(tonnes per year, dry basis)

Producer	Process	Capacity
FiberLean Technologies, UK	mechanical w. minerals	8,800
Borregaard, Norway	proprietary	1,100
Norske Skog, Norway	mechanical pretreatment	260
RISE, transportable container factory	enzymatic pretreatment	200
Daicel, Japan	high pressure homogenizer	200
CTP/FCBA, France	enzymatic pretreatment	25
RISE, Sweden	enzymatic pretreatment	25
Suzano, Brazil	mechanical	25
UPM, Finland	n/a	Pilot
Empa, Switzerland	enzymatic pretreatment	Pilot
InoFib, France	chemical pretreatment	Pilot
Stora Enso, Finland	enzymatic pretreatment	Pilot
Tianjin Haojia Cellulose, China	modified: TEMPO, other	Pilot
Weidmann Fiber Technology, Switzerland	mechanical	Pilot

Source: *Nanocellulose: Producers, Products and Applications - A Guide for End Users, TAPPI, 2017*. Updated, Biobased Markets, Sept. 2018.

Cellulose Filaments (CFs)

Cellulose filaments are a variant of MFC in which long, thin filaments are produced from pulp "by peeling the filaments from wood fibers using a mechanical process that uses no chemicals or enzymes."[iii] Cellulose filaments have a greater aspect ratio than MFC, i.e., 1,000 or more, with width of 80 to 300 nm and length of 100 to 2,000 µm.[iv]

Cellulose filaments were developed by FPInnovations and are now being commercialized by **Kruger Inc.** under the brand name FiloCell™. Kruger is the leading producer of CF with capacity of 6.000 tonnes per year. In addition, Performance BioFilaments, a 50/50 joint venture between Mercer International, Inc. and Resolute Forest Products, is working to develop commercial applications for cellulose filaments.[v] **Tianjin Haojia Cellulose Co., Ltd**., established in July 2013, is also reported to be producing cellulose filaments in the Tianjin Key Laboratory of Pulp and Paper, Tianjin University of Science & Technology.[vi]

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[i] Nelson, K. Containerboard Strengthening Performance of Lignin Containing (Unbleached) Cellulose Nanofibrils Depends on Fiber Source, Presentation at 2018 TAPPI International Conference on Nanotechnology for Renewable Materials, Madison WI, June, 2018.

[ii] Stora Enso Annual Report, 2017

[iii] https://fpinnovations.ca/media/factsheets/Documents/cellulose-filaments.pdf

[iv] i] https://biomaterials.kruger.com/products/the-filocell-advantage/

[v] www.performancebiofilaments.com/

[vi] http://www.xn--v5zvnq1bxbvs.com/gywm