TAPPI NANO DIVISION

Commercializing Cellulose Nanomaterials: Market Opportunities and Challenges

PRESENTED BY:

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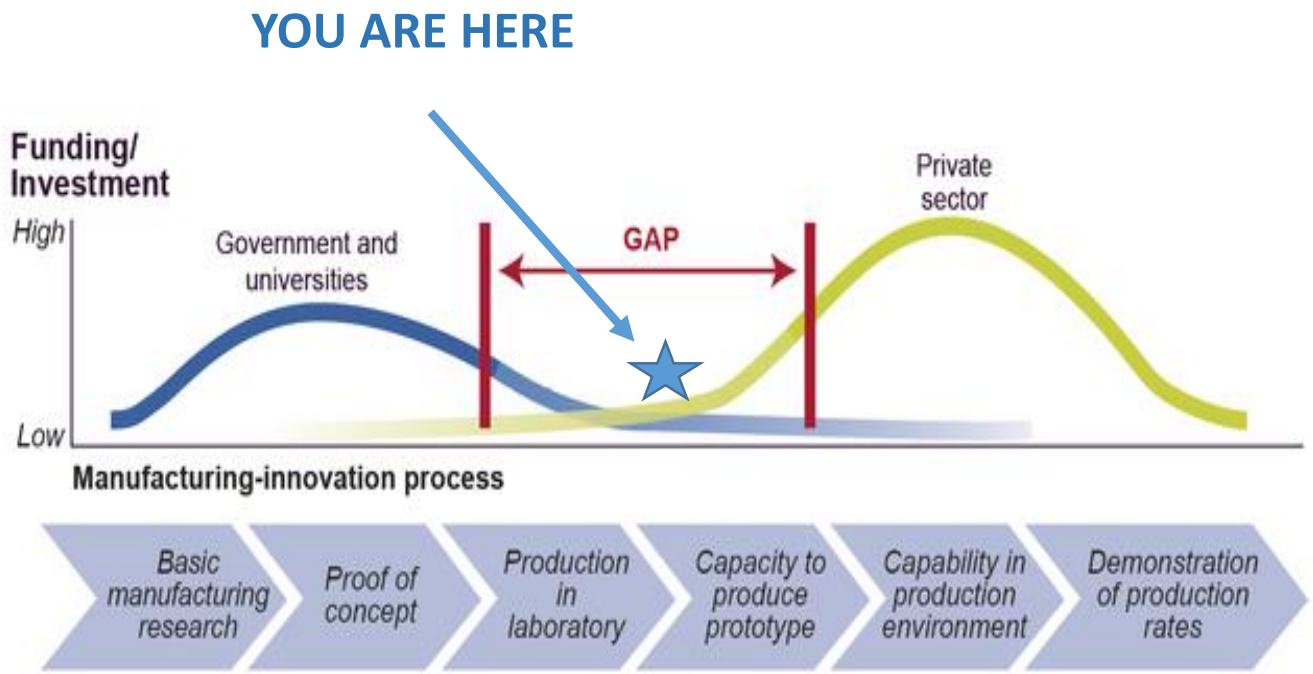
TAPPI

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

http://imisrise.tappi.org/TAPPI/Products/01/R/0101R350.aspx

Nanocellulose Challenges and Opportunities: End User Perspectives, TAPPI 2018

The road to commercialization



Source: GAO

Prove the business case through the supply chain!

Agenda

- Opportunities
- Technical Challenges
- Business Challenges
- The Business Case
- Recommendations

Opportunities

Films and barriers	63%
Composites	53%
Packaging	50%
Pulp and Paper	38%
Cosmetics	34%
Hygiene, personal care products	34%
Textiles	34%
Additive manufacturing (3D printing)	31%
Adhesives	31%
Automotive	31%
Paints and coatings	31%
Food	28%
Nonwovens	28%
Water treatment	22%
Cement	19%
Oil and gas	19%
Pharma	19%
Electronics	16%
Aeronautics	13%
Rubber	13%
Sporting goods	9%
Other	9%

Source: Nanocellulose Challenges and Opportunities: End User Perspectives, TAPPI 2018

Applications and potential volume
(thousand tons)

	Market size	Potential loading	Nano Cellulose potential
Paper and paperboard	400,000	5.0%	20,000
Textiles	50,000	2.0%	1,000
Paints and coatings	40,000	2.0%	800
Carbon black	15,000	2.0%	300
Films and barriers	9,670	2.0%	193
Composites	9,000	2.0%	180
Oil and gas	17,500	1.0%	175
Nonwovens	7,000	2.0%	140
Water treatment	4,650	2.0%	93
Excipients	4,600	2.0%	92
Cement	15,000	0.5%	75
Adhesives	500	2.0%	10
Cosmetics	300	1.0%	3
Battery separator	60	2.0%	1
TOTAL			23,063

Source: *Nanocellulose: Technology, Applications and Markets*, RISI 2014; updated Biobased Markets, May, 2017

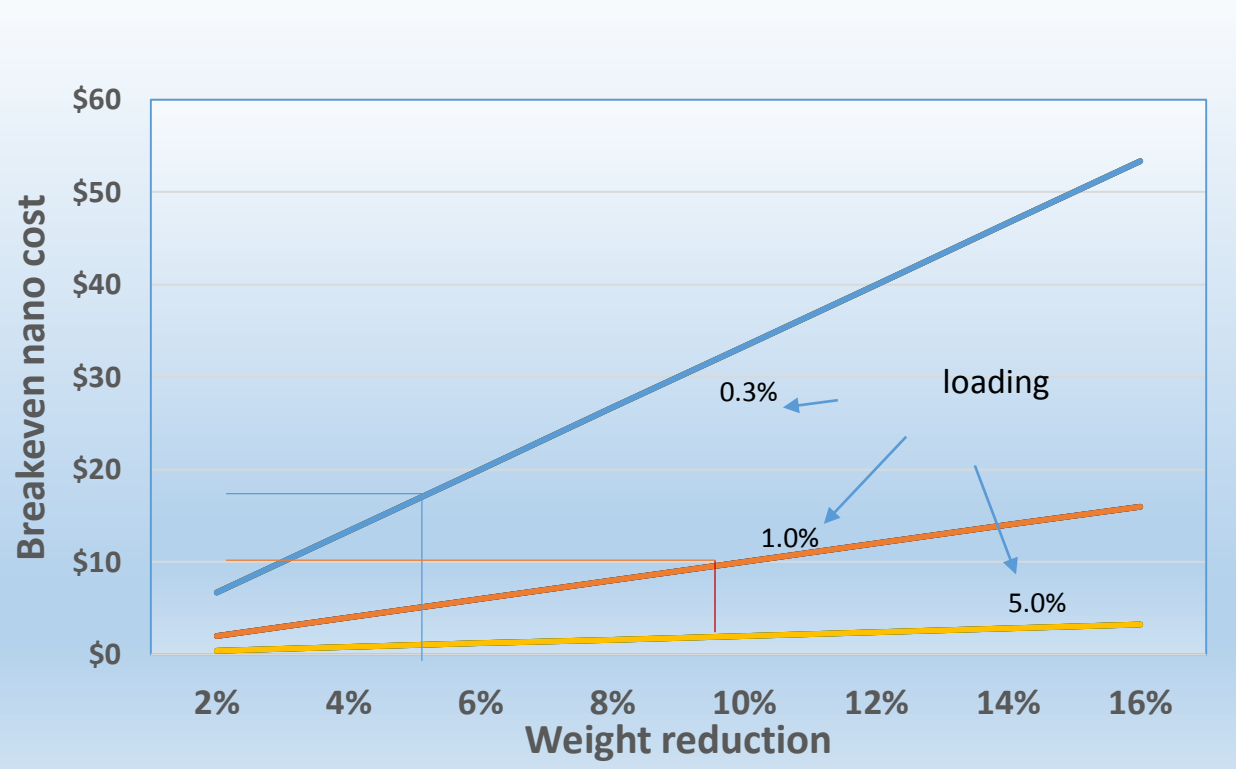
Technical challenges

- Drying and dispersion
- Compatibilization
- Cost
- Consistent quality from batch to batch
- Which material is best for a given application?
- What loading is optimal?
- Safety and regulatory issues

Commercial challenges

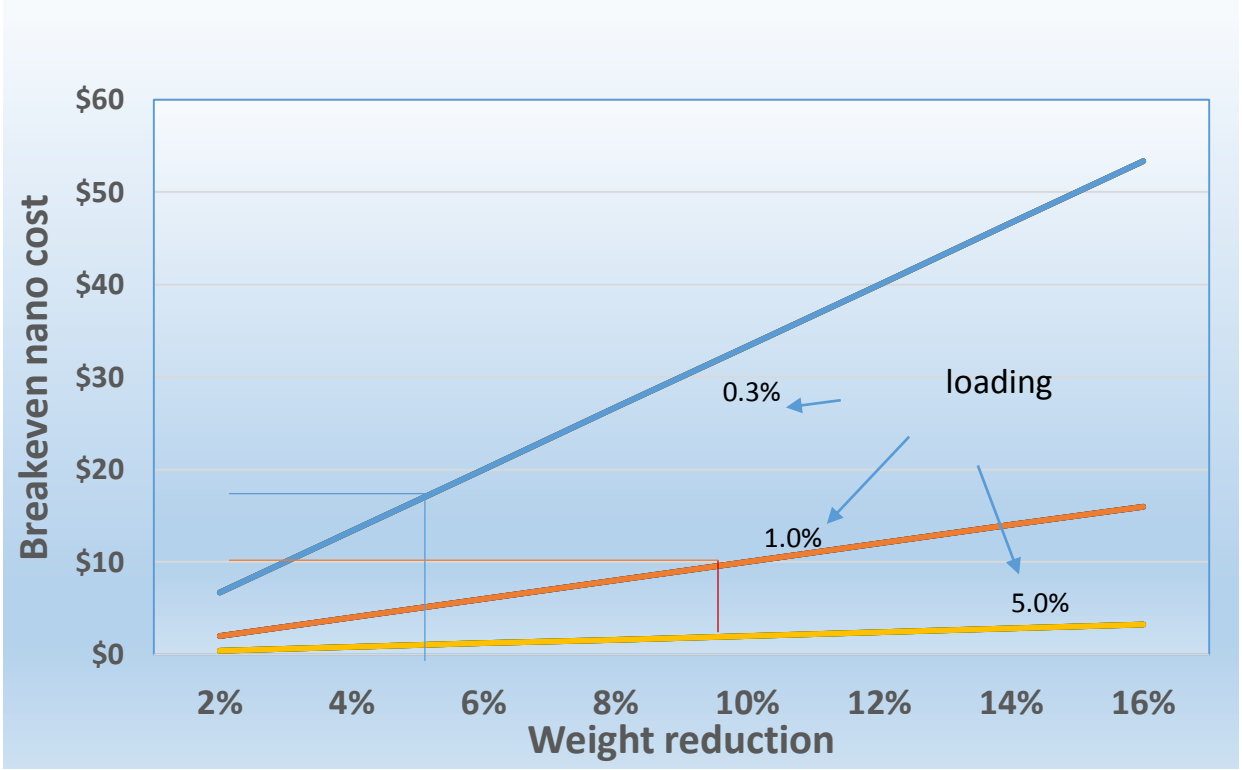
- Proof of concept
- Need solid value proposition through the supply chain
- Competitive materials
- Low oil prices
- Funding challenges: the Valley of Death
- Market development
- Applications development
- Who develops the applications? Who does the R&D? Who owns the IP?
- Which material is best for a given application?
- What loading is optimal?
- It is not a “drop in”: implications for customer process
- Scale up in production
- Scale up of applications
- Consistent quality from batch to batch
- Lack of multiple sources of supply
- Safety and regulatory issues

Cost alone does not define the business case



Source: Biobased Markets

Cost alone does not define the business case, nor does strength increase



Source: Biobased Markets

Paper and paperboard

- Release papers
- Barrier coatings
- Light weight
- Less softwood; lower cost pulps
- More filler, less fiber
- Wet end strength: productivity

Paper and paperboard

- FiberLean: 8,000 tpy MFC
- Norske Skog: 1 tpd MFC in SC magazine paper
- RISE transportable container factory: 200 tpy MFC
- Billerud Korsnas/Borregaard MFC: test market for packaging
- Stora Enso: 100 million MFC liquid cartons with Elopak in test market
- Kruger reports 7% bas wt reduction with 1% loading of FiloCell cellulose filaments

Textiles

- Reinforced synthetic fibers (acetate, aramid, Lyocell, polyester, etc.)
- Coatings: grease resistant - replace CFC
- Biopolymers (e.g. PLA)
- Moisture wicking
- UV blocking
- Clothing
- Automotive
- Carpet

Paints and coatings

- UV resistance
- Weather resistance
- Corrosion resistance
- Scratch and wear resistance
- Non burnishing
- Rheology: paint in fewer passes; non-drip

- Water based vs oil based: low VOC
- Eliminate less desirable materials: e.g., nanosilica

Films and barriers

- Light weight
- Cost reduction
- Enable use of biopolymers like PLA
- Barrier coatings
- Eliminate CFCs
- Eliminate non biodegradable, non recyclable plastics, foil, etc.

Composites

- Light weight
- Cost reduction
- 3D Printing – additive manufacturing
- Enable use of biobased materials like PLA
- Eliminate/reduce non biodegradable, non recyclable plastics

Composites

- Kyoto process: CNF reinforced resin for automotive and other applications
  - Seiko PMC
  - Nippon Paper
  - ASICS running shoe: first commercial application June1 , 2018
- Consortium: 222 companies in Japan
- U.S. DOE (Oak Ridge National Lab): auto parts, energy storage, etc.
- Patent activity:
  - WO2011100818 (FPInnovations): "a green approach for the development of nanocomposite materials comprising nanocrystalline cellulose (NCC) and appropriate vinyl polymers."
  - WO2011097700 (FPInnovations): Nanocomposite biomaterials of nanocrystalline cellulose (NCC) and polylactic acid (PLA)
  - WO2013037041 (CelluForce): NCC-based supramolecular materials" for thermoplastic and thermoset polymer composites
  - US9410288 (Ecolab): Use of nanocrystaline cellulose and polymer grafted nanocrystaline cellulose for increasing retention in papermaking process
  - US9322133 (American Process): Processes and apparatus for producing nanocellulose, and compositions and products produced therefrom

Oil and gas

- Rheology
- Improved temperature range
- Increased performance
- Increased cement strength

Oil and gas

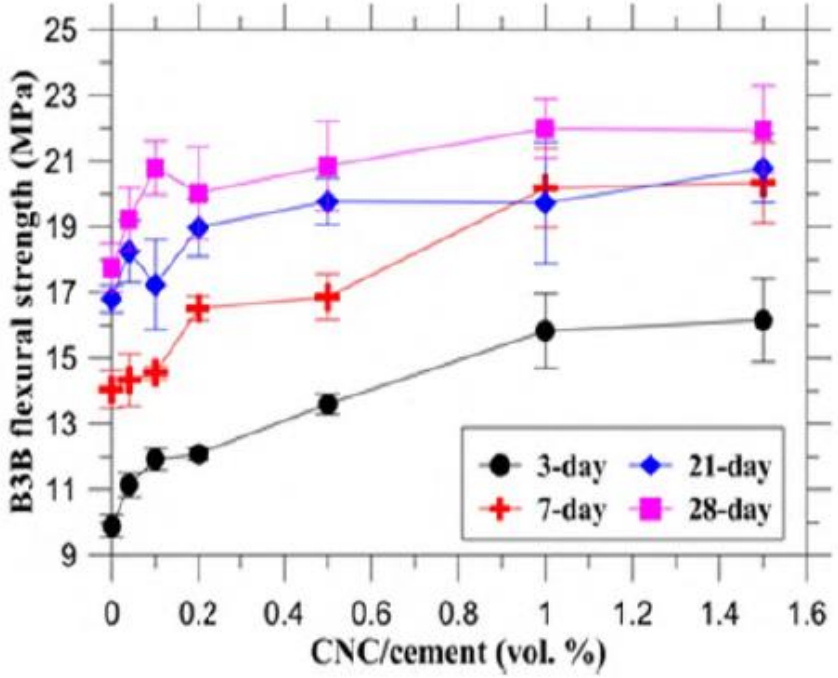
- Schlumberger: CNC introduced to conventional gravel pack fluids extends temperature performance.[1]
- UPM patent application WO2011089323, *Agent and composition for oilfield applications*, describes the use of CNF dispersed in water as a shear thinning agent.[2]
- Halliburton patent application WO2013116470 *Cellulose nanowhiskers in well services* describes a range of potential applications, e.g., for increasing the strength of a cement, or for increasing the viscosity of a water-based well fluid, a fracturing fluid, or a gravel packing fluid.[2]

Source:

1. Valerie Lafitte, Schlumberger, TAPPI Montreal 2017
2. Jack Miller, Nanocellulose Technology Applications and Markets, RISI, 2014.

Cement

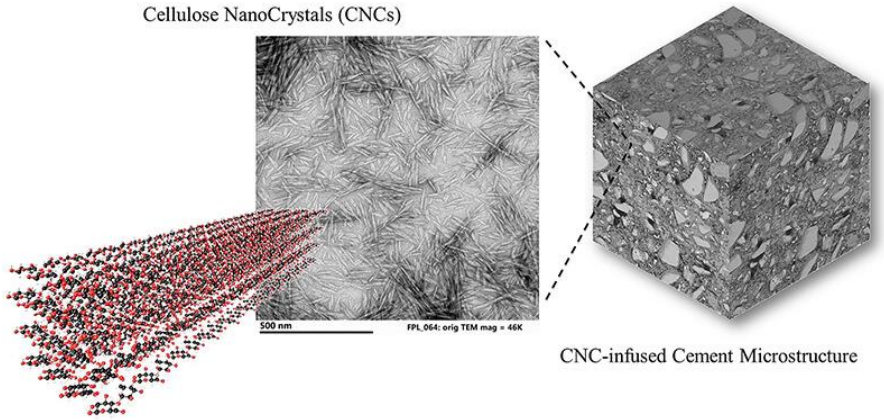
- Research at Purdue showed increased flexural strength up to 30%; increased hydration with 0.2% CNC



Source: Jeff Youngblood, Purdue University, High Performance Cement via Cellulose Nanocrystal Addition, TAPPI, Montreal, June 2017

Cement

- 2017: Nano-Green (Blue Goose) signs agreement to commercialize Purdue technology[1]
- Bridge to be built, California, summer 2018, using CNC enhanced concrete[2]



1. https://bluegoosebiorefineries.com/
2. https://www.purdue.edu/newsroom/releases/2018/Q1/purdue-researchers-show-concrete-infused-with-wood-nanocrystals-is-stronger,-plan-to-use-it-in-california-bridge.html

Recommendations

- Demonstrate the value proposition *through the supply chain*
- Get the cost down
- Collaborate

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Thank you

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