Cellulose NanoCrystals:
a biomaterial with great potential

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VP Business Development

CelluForce

About CelluForce

- World leader in the production of Cellulose NanoCrystals (CNC)
- Head Office in Montreal, Quebec, Canada
- Production facility located in Windsor, Quebec, Canada
- Shareholders

Domtar

FPInnovations

Fibria

Schlumberger

CNC & CelluForce's History

McGill — Academic research

FPInnovations — Technology Development

CelluForce — Commercialization

1947 — Initial work and observations by Rånby, and Marchessault

1961

1992 — Gray, Revol and Godbout work on **CNC** at McGill University

1997 — First **CNC** Patent by Gray, Revol and Godbout

2006 — First **CNC** pilot plant (1 kg/day)

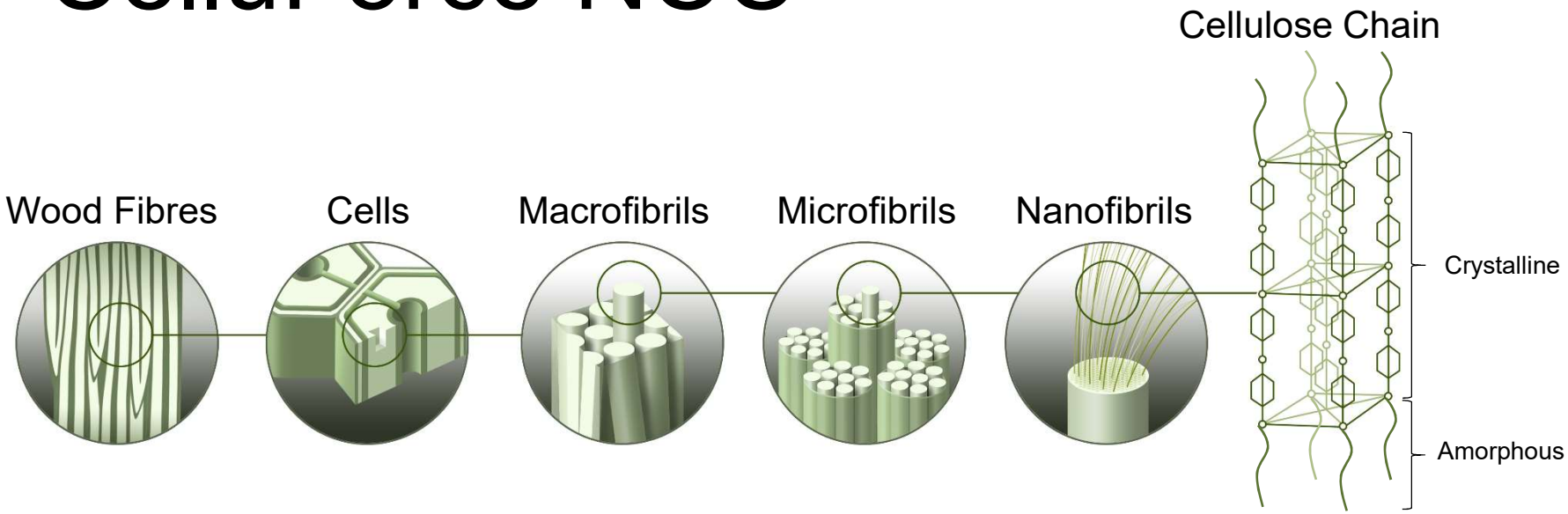
2011 — **Launch of CelluForce** by Domtar & FPInnovations

2012 — World first **CNC** production plant (300 tpy)

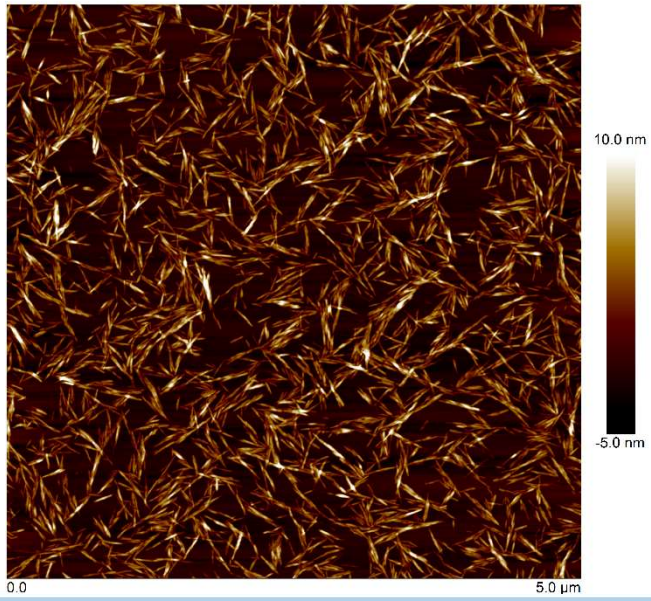
2015-16 — Schlumberger Investment

Fibria Investment

CelluForce NCC™



- Needle-shaped
- Nano-sized
  - 7.5 nm x 150 nm
  - 550 m^2/g



Crystal Extraction

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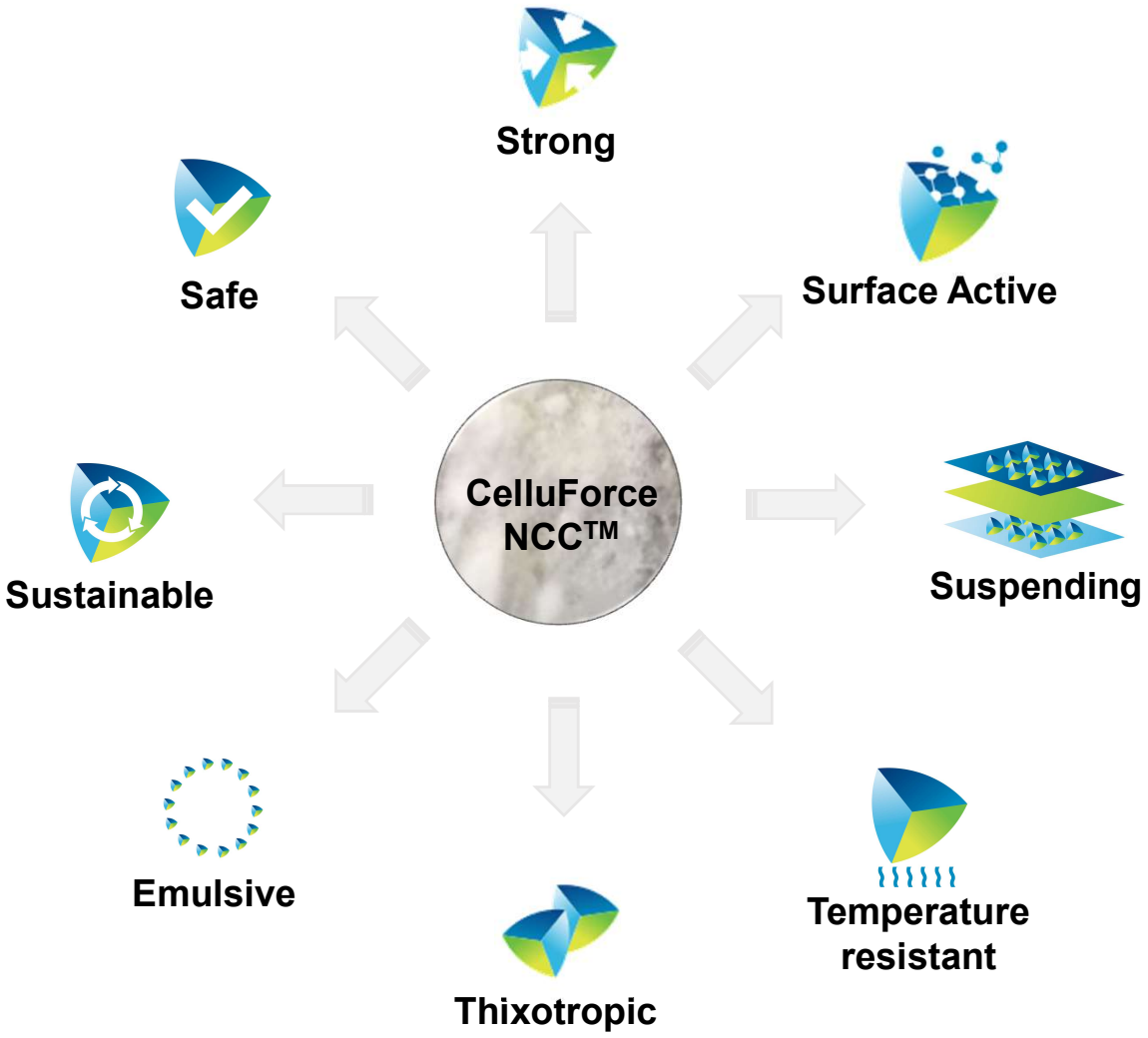
CelluForce NCC™ Properties

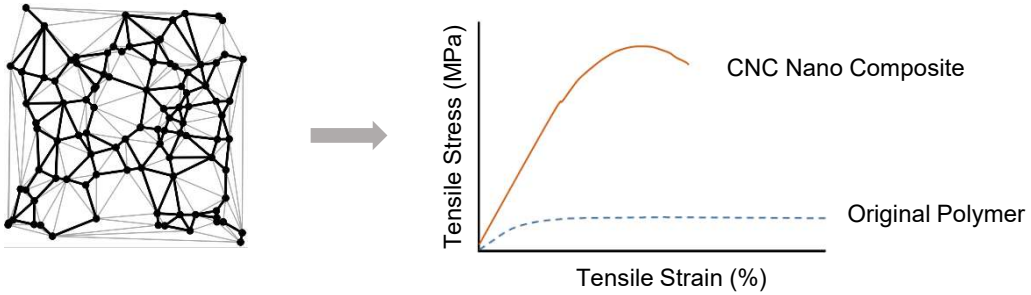


Strong

- Due to their crystallinity, each particle is very strong

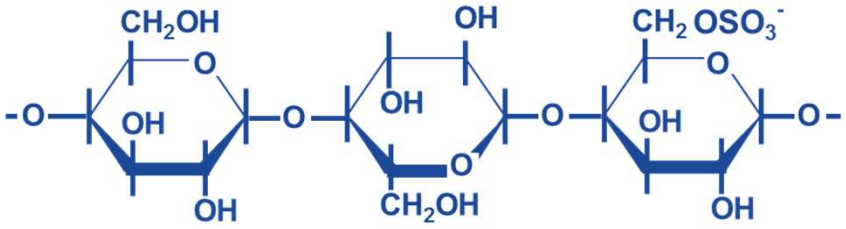
	Tensile Strength (MPa)	Young's Modulus (GPa)	Elongation at Break (%)
CelluForce NCC™	10,000	150	6.7
Carbon Fibers	4,000	235	1.6
Kevlar™ 29	2,800	180	4.0

- Allows to strengthen materials through percolation networks (nano dispersion)



Surface Active

- Surface comprised of hydroxyl and sulfate groups
- Allows to react other chemicals for new functionalities
- Inherently hydrophilic (NCV-100)
- Can be made hydrophobic (NCM series)
- Negatively charged (ionic interactions)
- Electro-magnetic response due to charges



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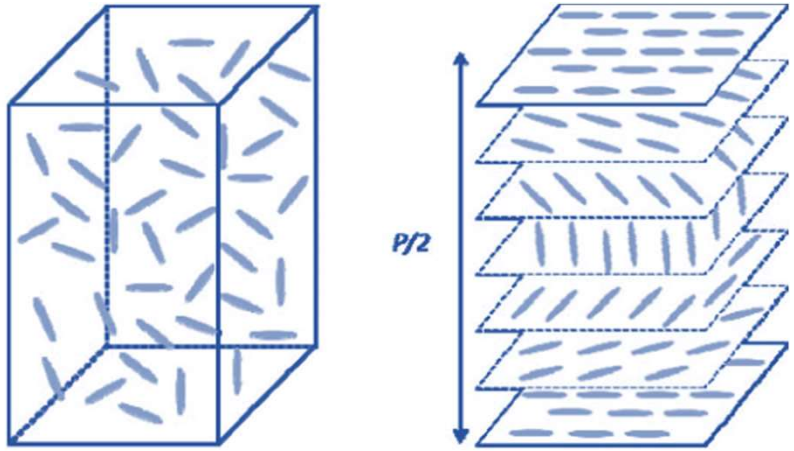
Suspending

- CNC forms liquid crystal
- Needles self-orient and form layers as the fluid is concentrated
- Structure allows a very robust suspension
- Also creates colour upon drying

Liquid crystal
Self-assembly
Chiral



Isotropic

Anisotropic

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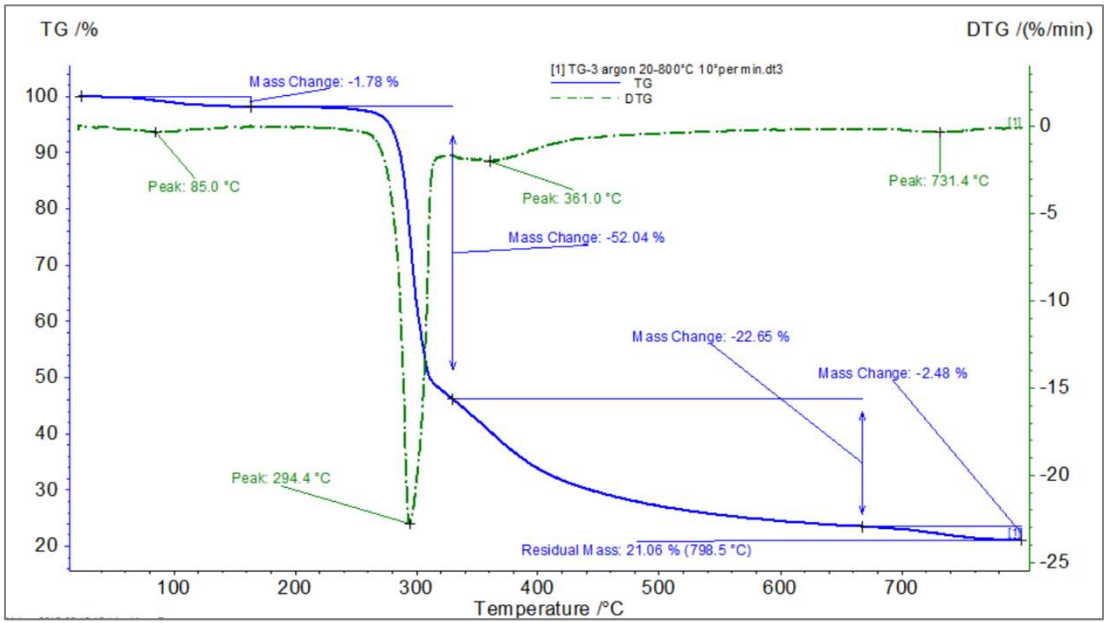
Temperature resistant

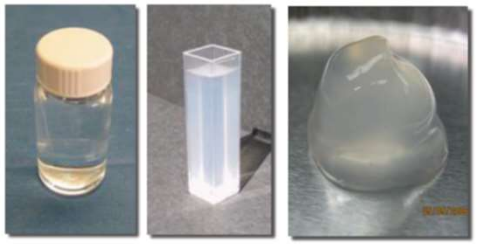
- The high purity of the CelluForce NCC™ allows stable properties up to the decomposition temperature of cellulose
- Good temperature resistance compared to surfactants
- Stable up to 280°C to 300°C



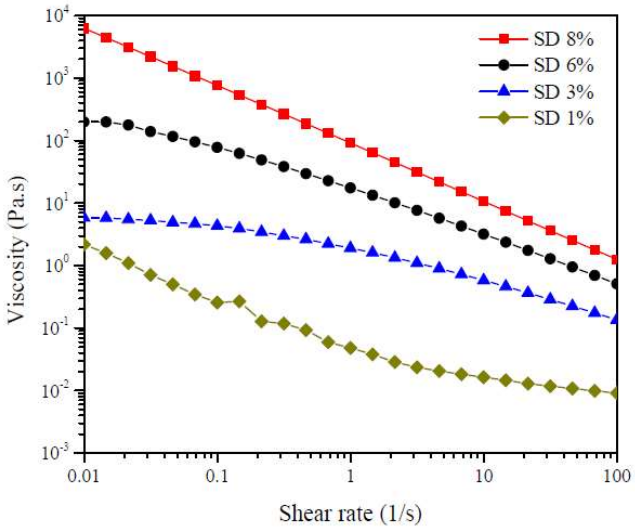
T increased 10°C/min in the range of 25°C - 800°C. Argon atmosphere with an argon flow rate of 10 mL/min

Thixotropic

- Large increase in viscosity with concentration



- Exhibits shear thinning properties



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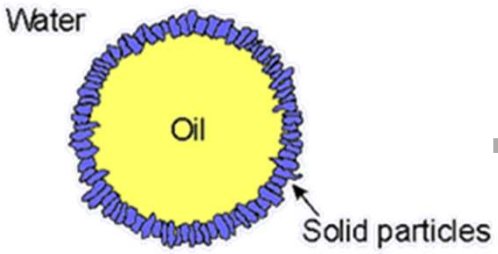
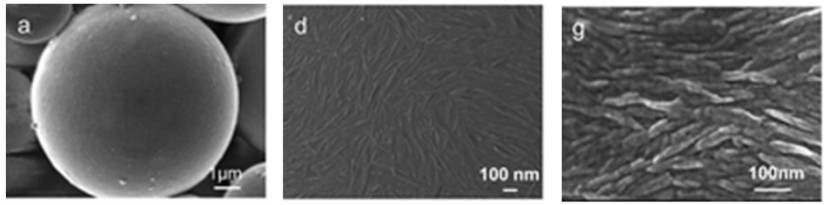
Emulsive

- High surface area
- High degree of interaction with its surrounding
- Forms Pickering emulsions
- Surfactant free stable colloidal suspensions



Pickering emulsions



SEM of CNC coated oil droplets

Sustainable

- Made from an abundant and renewable resource
- Captures green house gases
  - 1 m^3 of wood can sequester 1 m^3 CO_2
- Replaces petrol based products
- Overall reduction of carbon footprint

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Safe

- Numerous human health and safety tests have shown that CelluForce NCC™ is benign
  - Oral, inhalation and dermal tests for acute toxicity to mammals, show that CelluForce NCC™ falls into the least toxic classification
  - In vitro and in vivo tests show CelluForce NCC™ to be within acceptable limits
  - The dried form aggregates in 10 – 30 µm particles allows standard respiratory protection to be used for workers
- Celluforce NCC™ has been added to Canada's DSL allowing its unrestricted production and sale
- Celluforce NCC™ is exempt from REACH under the polymer exemption rule
- Celluforce NCC™ complies with TSCA regulations in the United-States

Environment and Climate Change Canada

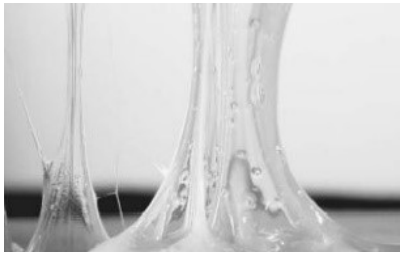
UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

COMPLIANT · COMPLIANT REACH

Markets and Applications

Oil and Gas

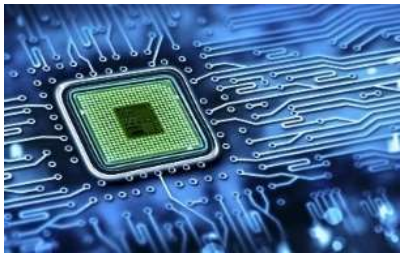
Paints, Inks and Coatings



Adhesives

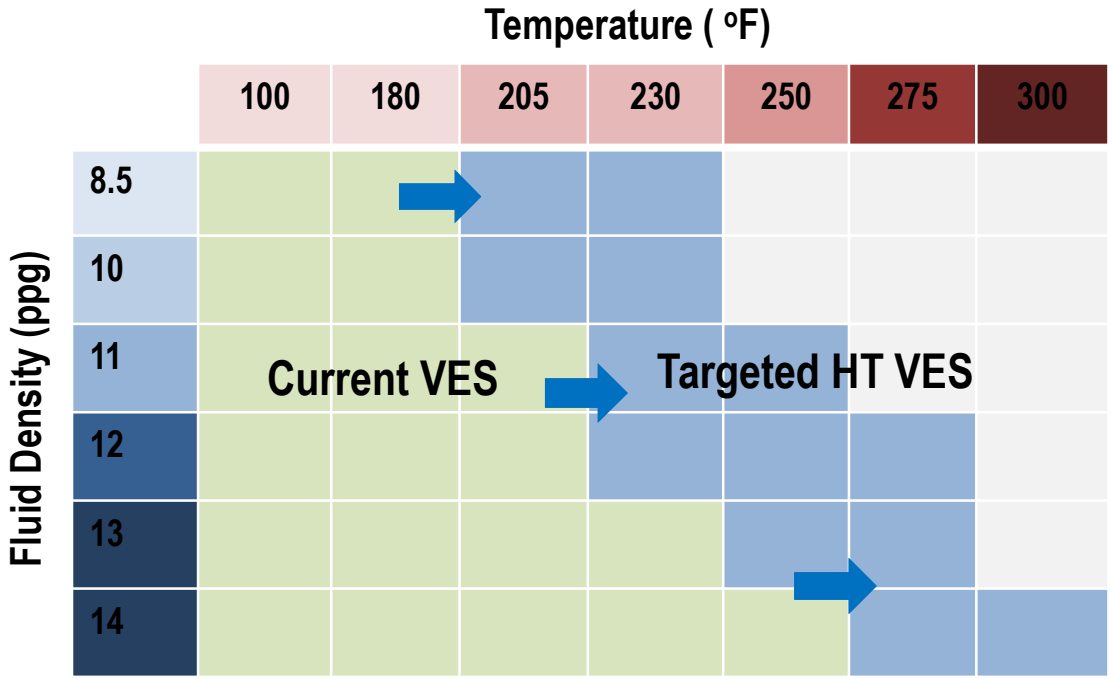
Plastics and Composites

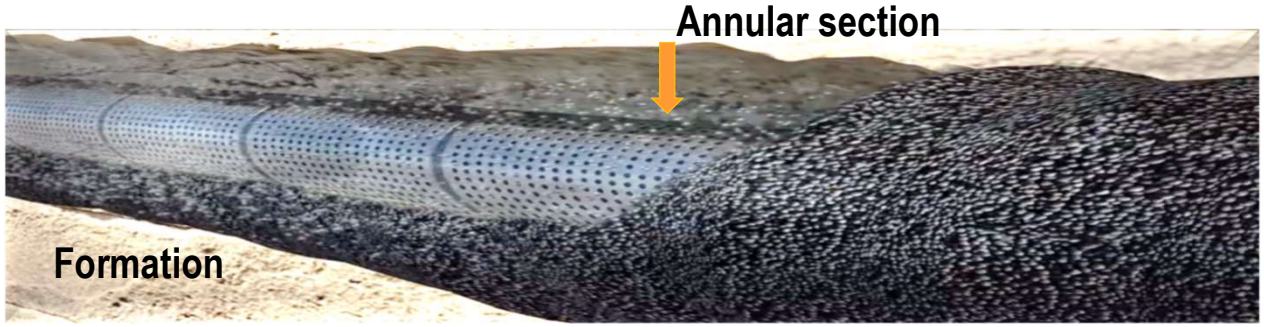
Rubbers and Elastomers



Electronics

Oil Production Sand Control





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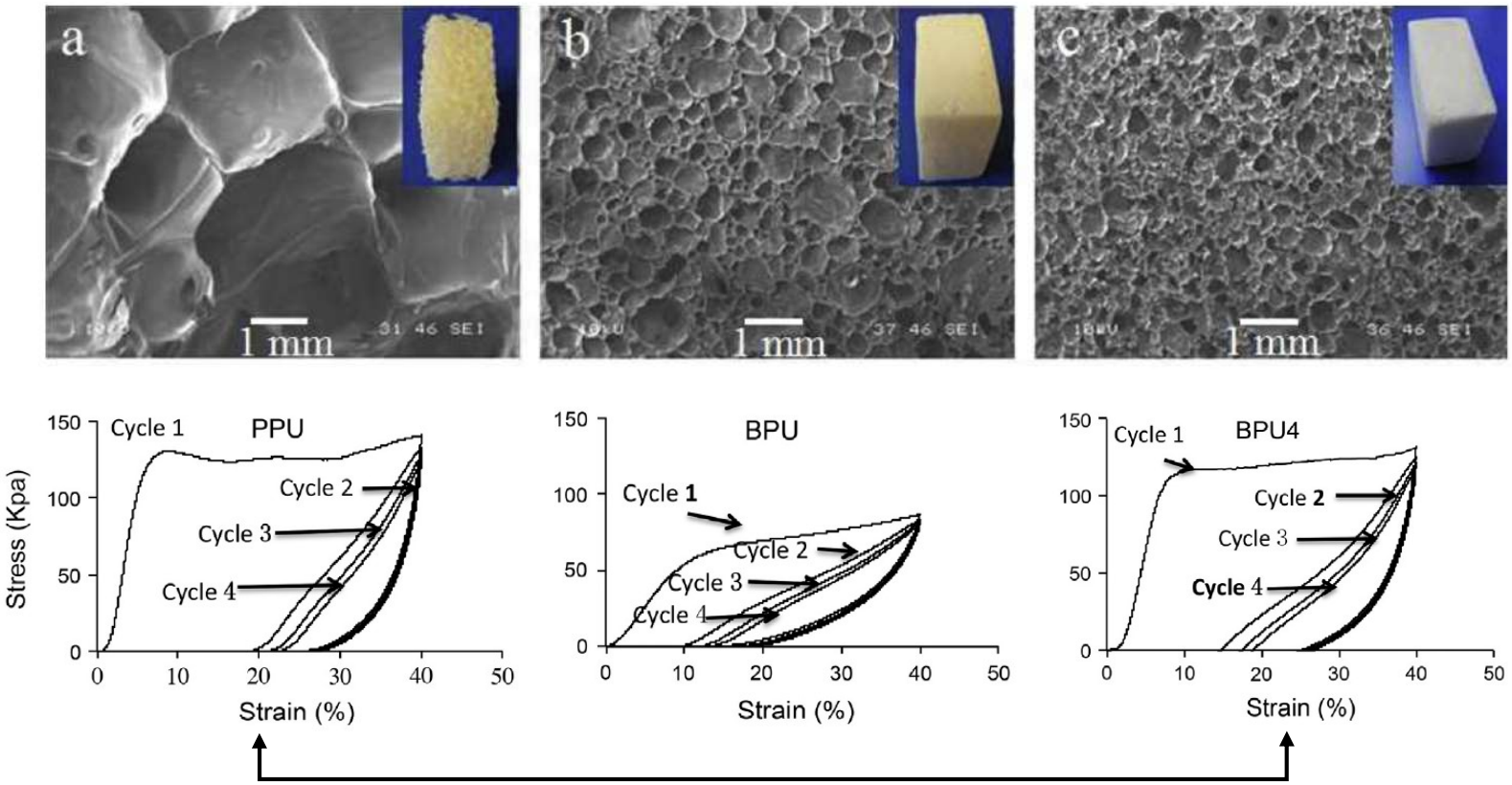
Biopolyurethane (BPU) Foams



Match properties of petroleum PU (PPU) Foams

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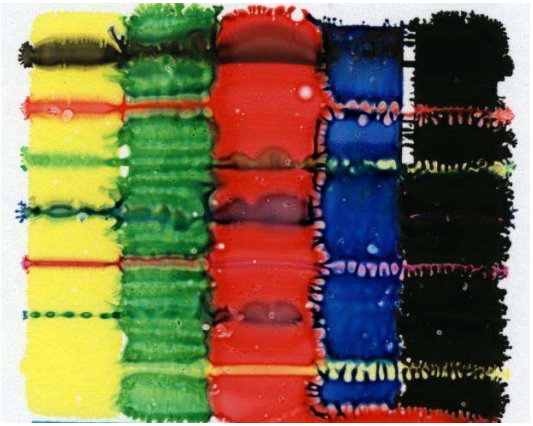
Source: Zhou et al, 2015

Phenol Formaldehyde Resin

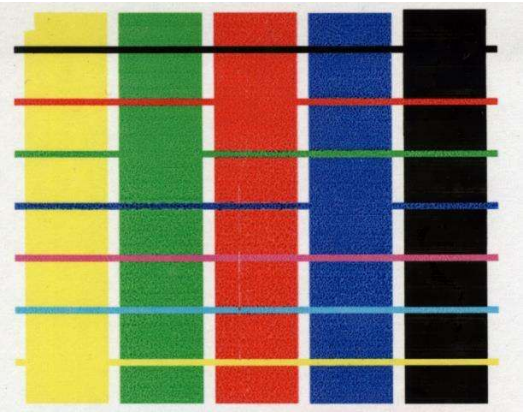
- Development of a new glue mix
  - Commercial PF resin
- No change of panel production conditions
- Benefits
  - Simplify formulation
  - Improved panel strength
  - Stable glue mix, long pot life

Plastic Films Coating

- Improved ink drying
- Improved print quality
- Improved wet/dry ink rub
- Reduced oxygen transmisson rate



Water-based multicolour inkjet print on Mylar film



Water-based multicolour inkjet print on CNC coating on Mylar film.

PVOH

- Improvement of tensile strength, stiffness and elongation at break

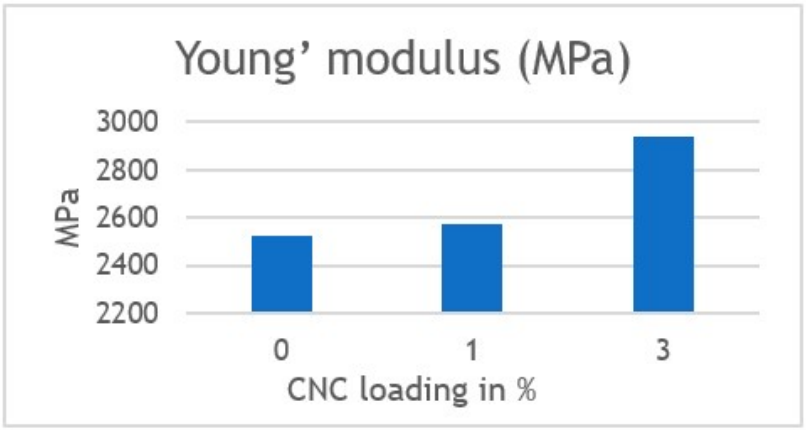
  → potential down-gauging of films

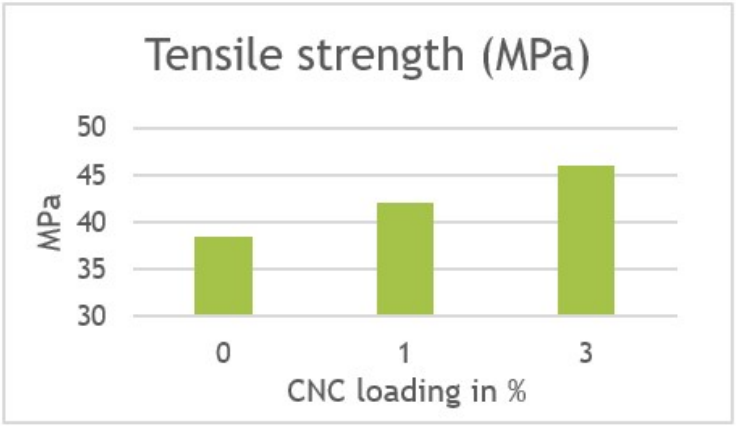
- Improvement of water-vapor impermeability

  → potential use for food-packaging

- No impact on optical properties and thermal stability

  → no major changes to the current film processing method





Source: Alves Silvério, H. et al – 2013 – Journal of Nanomaterials & Pereira, A. et al. – 2014 – Elsevier

Collaboration is Essential

+

CelluForce's CNC knowledge

Industrial partner's application knowledge

= Success

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Harness the power of nature
to create better products