Emerging technologies to develop active packagings

September, 7th, 2017

Budapest, ActInPak Meeting

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Introduction to active packaging

Packaging is important in our society

- Way of life indicator:
  - Europe: 116 kg/person/year
  - USA: 200 kg/person/year
  - Third World: 25% of food lost due to lack of packaging

- Packaging:
  - 5 to 10 % of product value
  - Protects 10 x its weight
  - Represents 40% of Homewaste
  - 1h/day less of Housekeeping thanks to packaging

Introduction to active packaging

SOCIETY IS CHANGING

. **« From eating more quantity to eating best quality »**

diversity, safety, functional food, nutrition

⇨ food tracability, tamper proof packaging

. ***Social & economical evolution***

- **↗ level of life**,
- **New marketing target** : children, old person
- **↗ women's employment:**from 40% to 80% between 1965 & 1999,
- **New family** : mono-parental, single (1 foyer sur 3)
- **Less time for shopping:** from 1h30 in 1980 to 30 min en 2001
- **less time for dinner :** 1/3 of population eat « stand up » their lunch during week

⇨Precooked dish, frozen food, fast food, higher shelf life food

=>New packaging systems are expected

Introduction to active packaging

Active & Intelligent Packaging

Standardized field *[DeJong, 2005; DeKruijf, 2002, Veermeiren, 1999]*

- Active Packaging: **change packaging conditions** to increase shelf life & safety of food by keeping quality

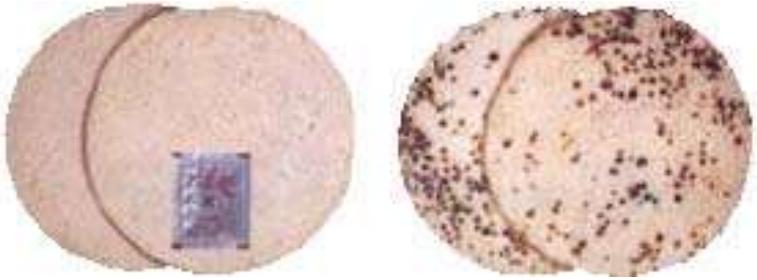
3 types:	*1. Barrier & MAP,* *2. Scavenger (O_2, humidity, …),* *3. Anti-microbial*

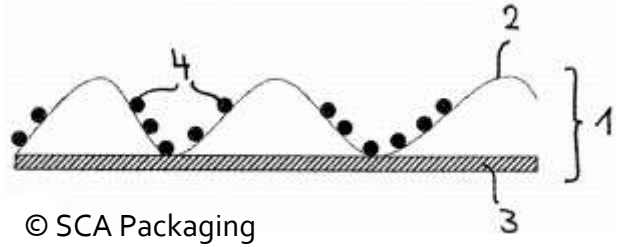
- Intelligent Packaging: **monitor the quality** of the food product or its surrounding environment to predict or measure the safe shelf life better than a best before date

Ex: ITT, leakage Indicator, freshness indicator

Introduction to active packaging

Introduction to active packaging





© SCA Packaging

??

New active packaging systems = Need New Technologies

OUTLINE

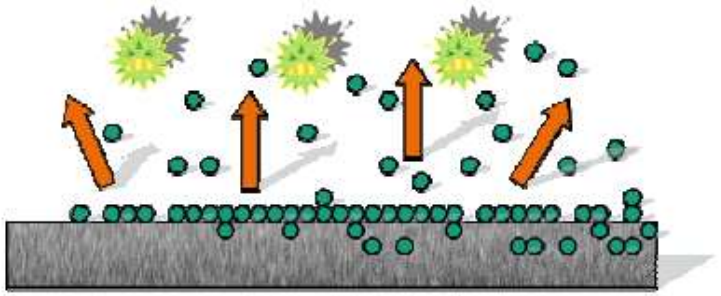
- NEW SOLUTIONS IN MATERIALS
  - Antimicrobial Peptides for Bioactive Packaging
  - Cellulose nanofibers (CNF) as a new opportunity
- NEW SOLUTIONS IN PROCESSES
  - Encapsulation systems in the packaging material
  - Electrospinning for active materials
- NEW CONCEPTS IN ACTIVE PACKAGING
  - Bionanocomposites for active packaging

New Materials

Antimicrobial Surfaces and Coatings

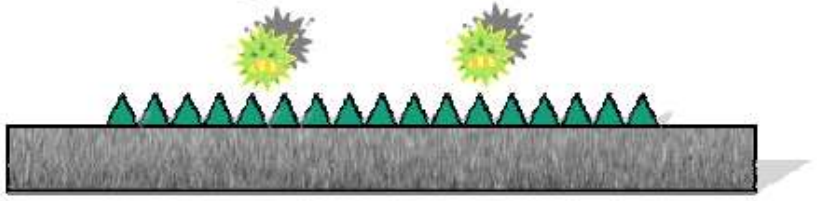
Release-Mechanism

- Diffusion
- Decreasing effect over time



Contact-Mechanism

- Surface immobilized substances
- Antimicrobial effect by direct contact
- Deposits influences effect
- Structures (e.g. Lotus effect)



Examples:

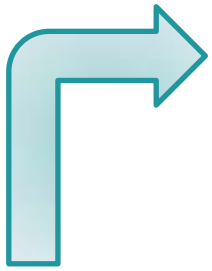
- Triclosan (Textiles, Microban®)
- Enzymes (e.g. Lysozyme)
- Organic acids (e.g. sorbic acid)
- Bacteriocines (e.g. Nisin)

Examples:

- Chitosan (Textiles)
- Silver (consumer articles, AgION™)
- Quaternary ammonium compound

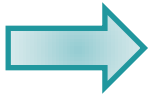
Adapted from Muranyi, Flexpak workshop, 2011

New Materials

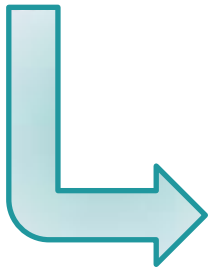


Antimicrobial peptides

New Materials
For Active packaging

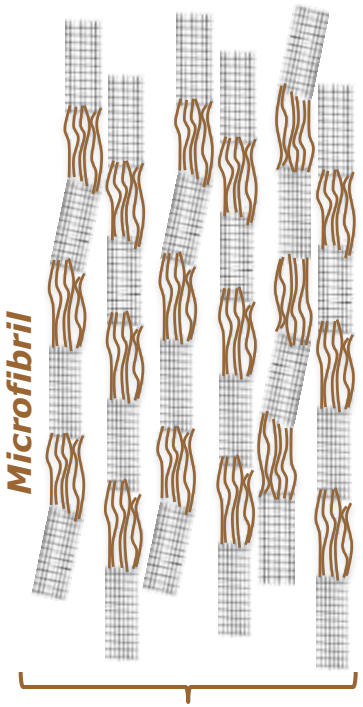


Nanocellulose

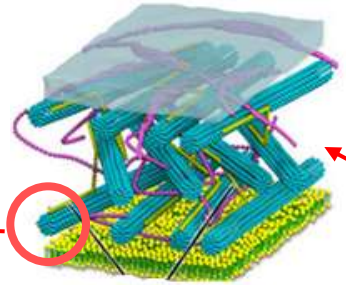


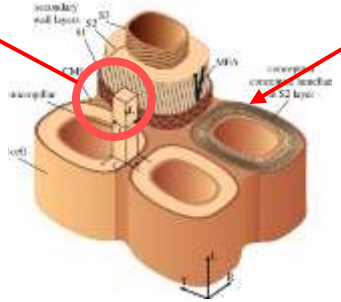
New Oxygen Scavenger

NanoCellulose



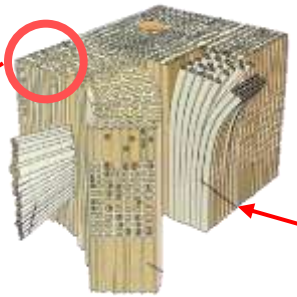
Cellulose microfibril in cell walls





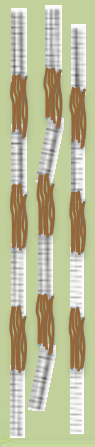
Cell wall layers

Wood cells

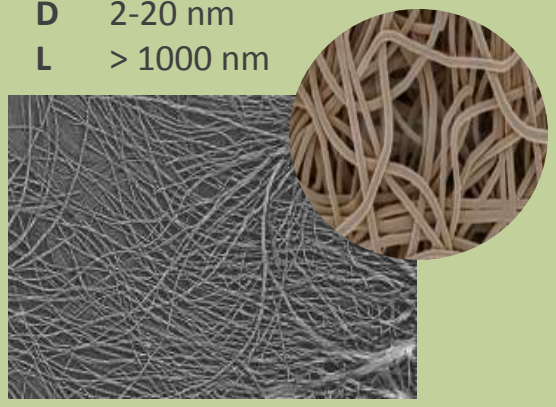


Forest product, biomass

Microfibrillated cellulose (MFC)



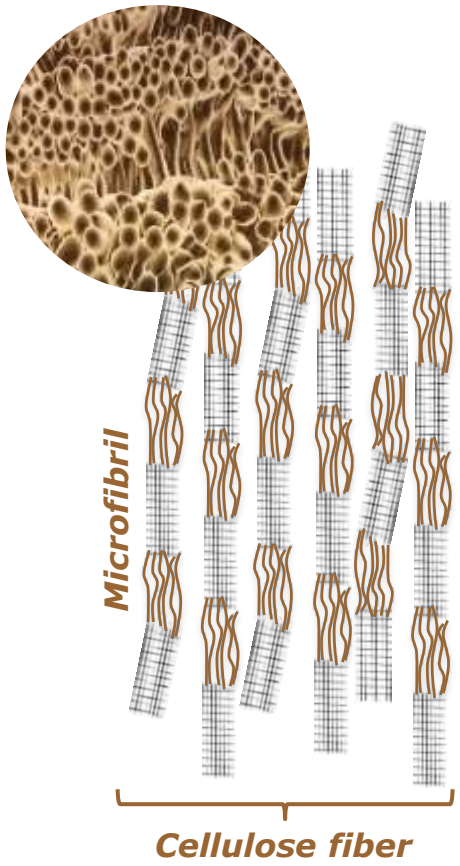
D 2-20 nm
L > 1000 nm



Cellulose Nanocrystals (CNC)

D 2-20 nm
L 200-1000 nm

Nanocrystals and sustainable process



2. Mechanical

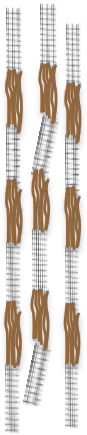
Homogenization

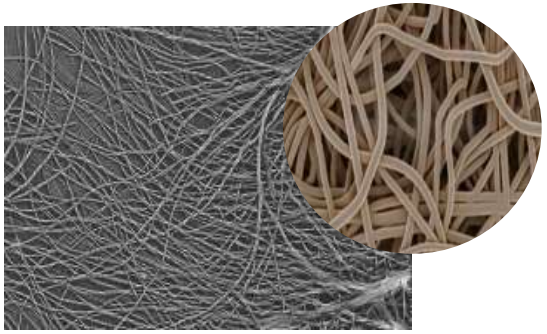
1. Defibrillation

1. Hydrolysis

2. Dialysis /UF

Microfibrillated cellulose (MFC)



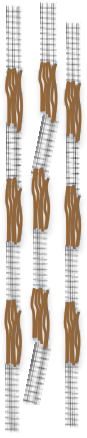


D 2-20 nm
L > 1000 nm

Cellulose Nanocrystals (CNC)

D 2-20 nm
L 200-1000 nm

Nanofibrils & process



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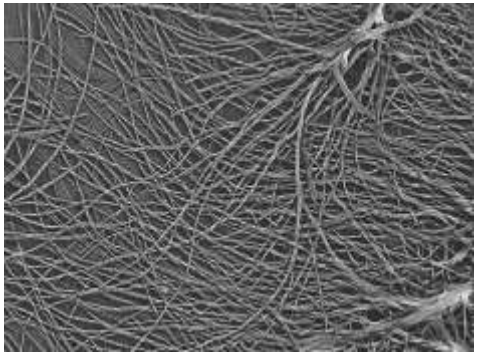
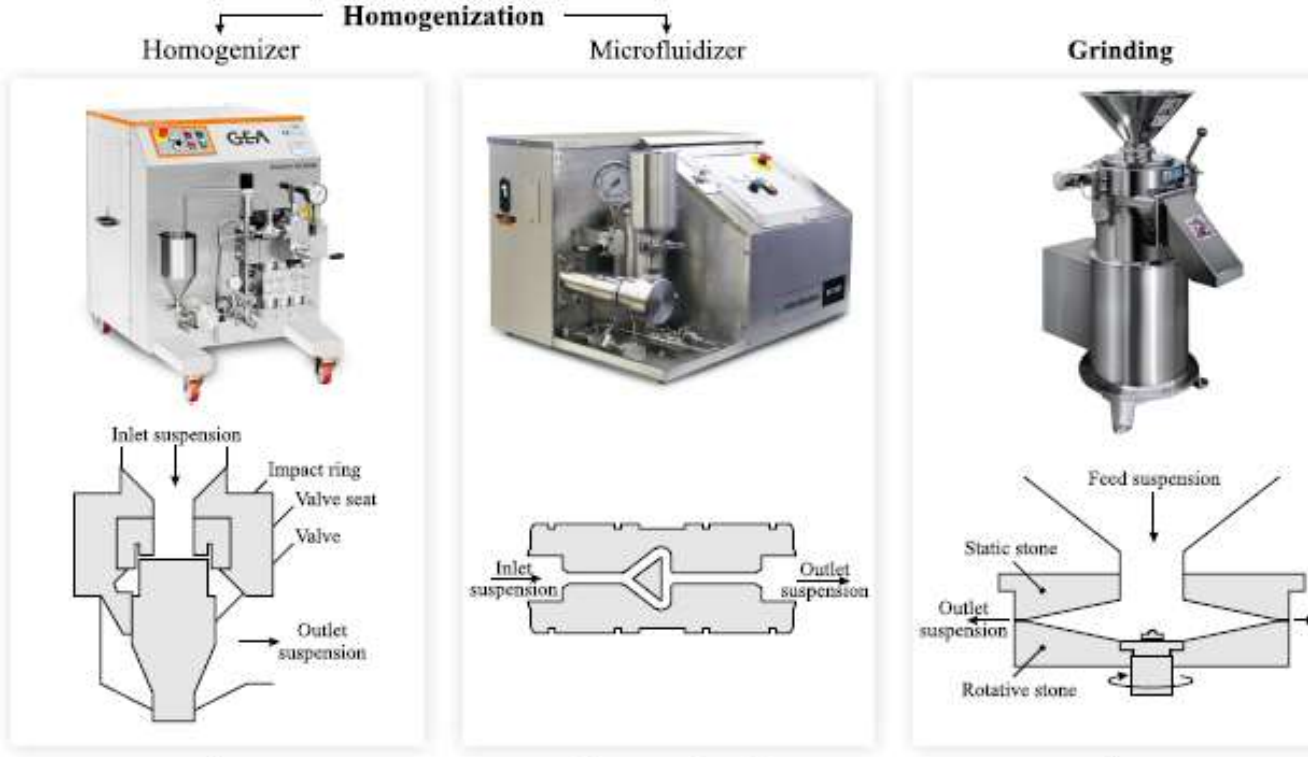
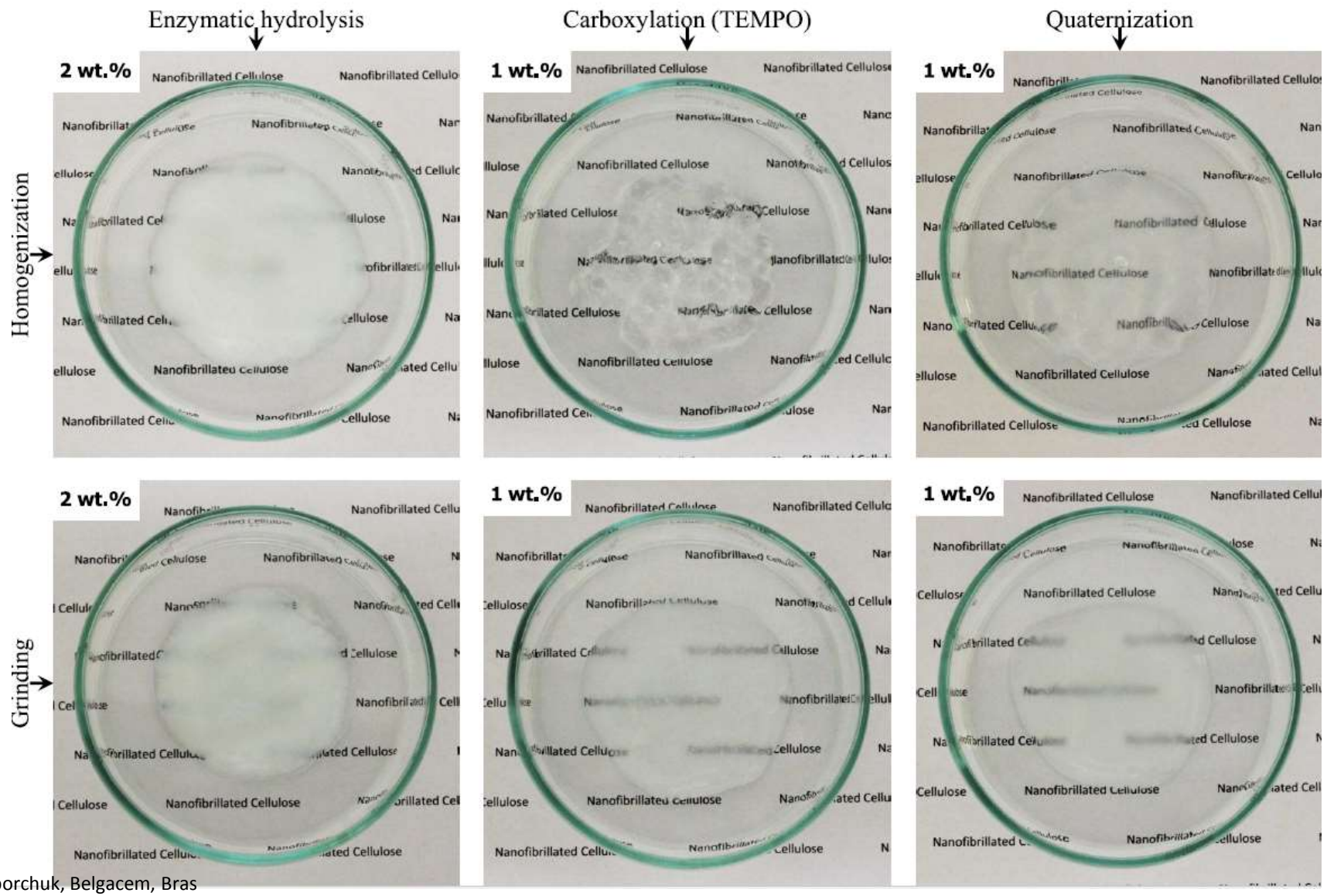
Microfibrillated cellulose (MFC)





Nechyporchuk, Belgacem, Bras
Production of cellulose nanofibrils: a review of recent advances,Ind crops (2016), in press

CNF Pre-treatment



Nechyporchuk, Belgacem, Bras
Production of cellulose nanofibrils: a review of recent advances,
Ind crops (2016), in press

Development of nanocellulose interest

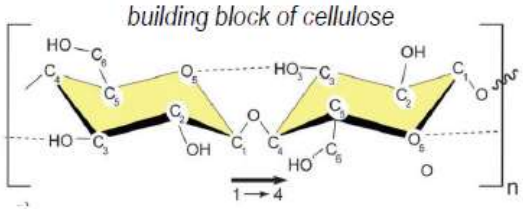
Nanocelluloses

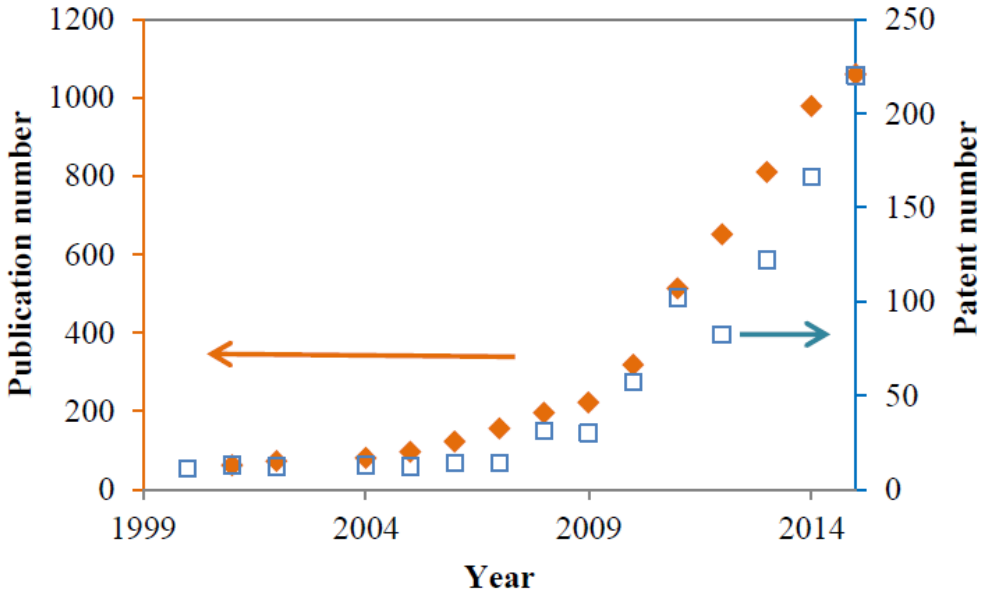
Nanomaterials

- 1 dimension < 100 nm
- high surface area (>100 m² /g)
- novel characteristics

Cellulose

- most available biopolymer on earth
- 200 billion tons / year (3 % used)
- many sources available





Evolution of annual non-cumulative number of publications and patents on nanocellulose

(Source: SciFinder, July 2016 – descriptors : cellulose nanofibrils, cellulose microfibrils, cellulose nanocrystals, cellulose nanowhiskers, microfibrillated cellulose)

NanoCellulose

De-risking scale-up
GOVERNMENT & INDUSTRY CO-INVESTMENT

World's first **Cellulose Nano-Crystals** plant

1 ton/day - Joint Venture (CelluForce) with Domtar
- Capital: $45 M
- R&D to Demo: $10.5 M

Windsor QC - 2012

World's first **Cellulose Filament** plant

5 ton/day - Strategic alliance with Kruger
- Capital: $43 M
- R&D to Demo: $21.5 M

Trois-Rivières QC - 2014

Canada's first **Lignin Separation** plant

30 ton/day - Licensing to West Fraser (>$10M)
- Capital: >$10 M
- R&D to Demo: $12.5 M

Hinton AB - 2014

Stuthridge, Tappi2017

NanoCellulose

2015

Europe's first pilot facility for nanocrystalline cellulose will be based on technology developed by Melodea by the end of 2016

Europe's first pilot facility for nanocrystalline cellulose

MoRe Research, alongside Holmen and SP Technical Research Institute of Sweden, is investing in nanocrystalline cellulose by building a pilot facility in Örnsköldsvik.

The facility will be the first of its kind in Europe and represents an important step, allowing interested companies to develop nanocrystalline cellulose from cellulose-based material on a large scale.
Nanocrystalline cellulose has many interesting material properties, and can be used for example as a building material, in biocomposites, printed electronics and dye additives. The operation in the pilot plant is based on technology developed by an Israeli start-up company Melodea.

Melodea
Bio Based Solutions

NanoCellulose

Flagships in Call 2016

Objective: deployment of a technology, which has been already demonstrated leading to a system, which is complete and qualified (TRL8) for successful commercial operation (large scale production facility in Europe)

TOPIC	FOCUS
BBI.VC1.F1	BIOETHANOL: second generation bioethanol production built on lignocellulosic non-food feedstock (straw)
BBI.VC2.F2	Microfibrillar Cellulose (MFC): large-scale supply and market creation of MFC to demonstrate an industrial symbiosis between the biomass and the forest industry
BBI.VC1.F1	CELLULOSIC ETHANOL: Cellulosic ethanol from unused crop residues and crops grown on marginal lands

ırregaard / News / EUR 25 million in EU funding for Exilva

Borregaard Receives EUR 25 million for Commercialization of Microfibrillar Cellulose from the EU

Borregaard Receives EUR 25 million for Commercialization of Microfibrillar Cellulose from the EU

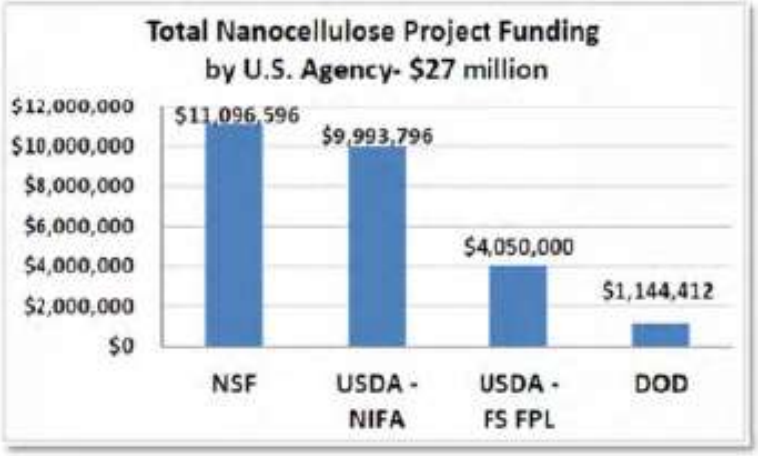
Borregaard has received a funding commitment of EUR 25 million (NOK 232 million), for the development and commercialization of

=> Nanocellulose = 2nd **priority** of european Bioeconomy
=> Not only fashionable but also **sustainable**

NanoCellulose

Governments throughout the world have recognized the potential economic and societal benefits of nanocellulose and have made significant R&D investments:

- CANADA: ~$71 million
- EUROPE: ~$25 million
- USA: ~$27 million
- JAPAN: ~$38 million *annually*

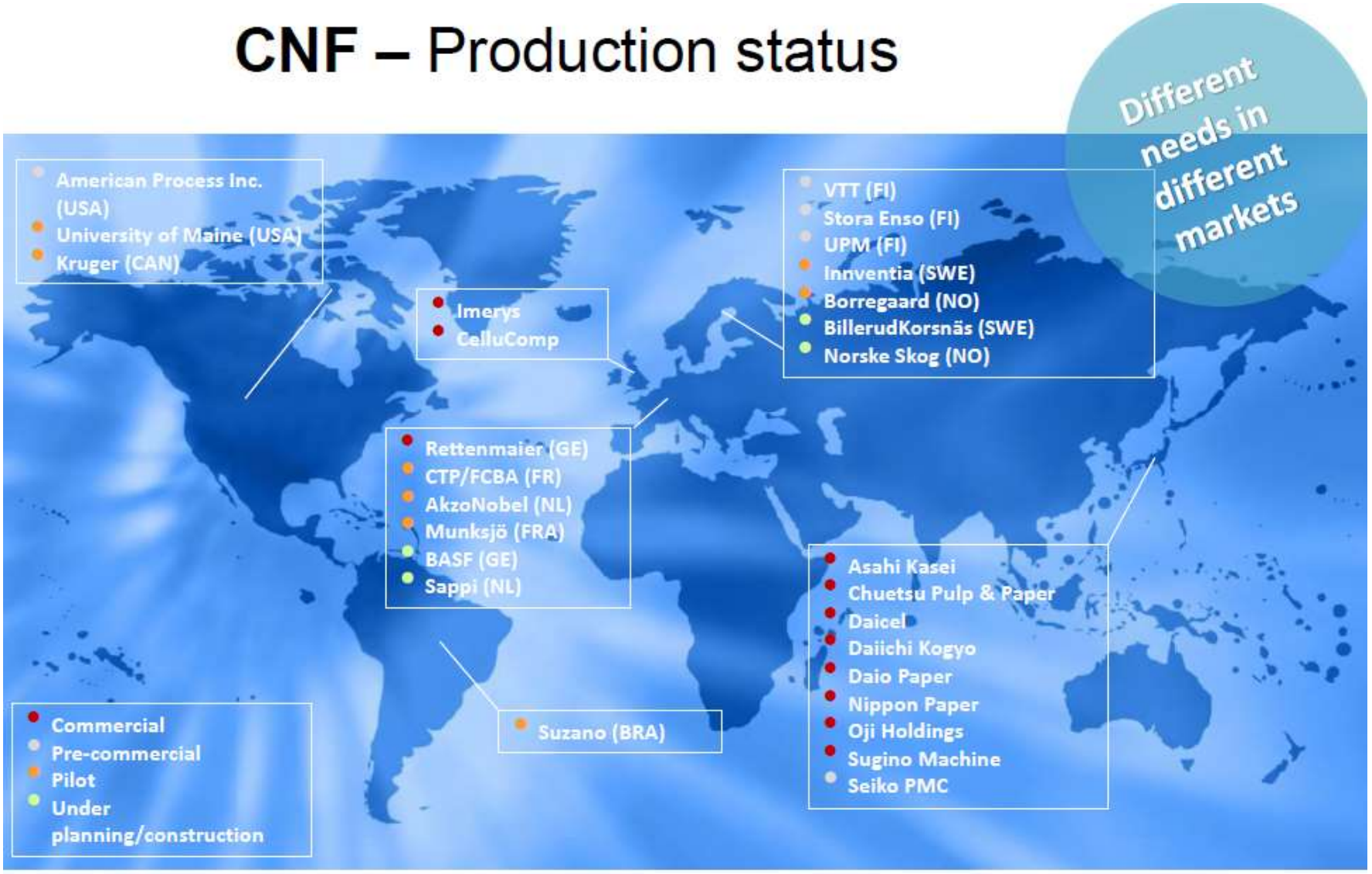


Growing interest among US Federal Agencies in nanocellulose research. RFPs on *specific* nanocellulose topics issued in 2017 by DOE and USDA.

Source: Agenda 2020 Cellulose Nanomaterials Working Group, Global Partnerships Workshop, 2016 TAPPI International Nanotechnology Conference, Grenoble, France

Nanocellulose

CNF – Production status



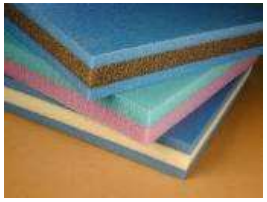
P. Qvintus, 2015, tappi Atlanta

NanoCellulose

23 million tonne potential

(figure in ktons)

	Market Size	Potential Loading	Nano Cellulose Potential	Potential @ 5% Market Penetration	CNF Potential	CNC Potential	CNF	CNC
Paper and Paperboard	400,000	5.0%	20,000	1,000	95%	5%	950	10*
Paints and Coatings	40,000	2.0%	800	40	5%	95%	2	38
Composites	9,000	2.0%	180	9	5%	95%	0	9
Films and Barriers	9,670	2.0%	193	10		100%	0	10
Excipients	4,600	2.0%	92	5	10%	90%	0	4
Natural Textiles	34,500	2.0%	690	35		100%	0	35
Manufactured Textiles	56,300	2.0%	1,126	56		100%	0	56
Cement	15,000	0.5%	75	4	5%	95%	0	4
Oil and Gas	17,500	1.0%	175	9	10%	90%	1	8
Nonwovens	7,000	2.0%	140	7		100%	0	7
Adhesives	4,000	2.0%	80	4	5%	95%	0	4
TOTAL			**23,551**	**1,178**			954	184



Source: RISI, *Nanocellulose: Technology Applications, and Markets*

NanoCellulose

2014: Thomson Reuters names nanocellulose as one of the top 10 technologies that will change the world by 2025.

CANADA 2015: Schlumberger invests in Celluforce for CNC in oil and gas.

JAPAN 2015: Mitsubishi Pencil Co Ltd and DKS Co Ltd commercialize pen ink containing CNF

JAPAN 2015: Nippon Paper commercializes deodorant adult diapers using TEMPO CNF.

FRANCE 2016: IMERYS and Omya form Fiberlean Technologies JV for MFC across various applications

FiberLean Technologies

FINLAND 2016: UPM commercializes GrowDex® CNF hydrogel for 3D cell culture applications in biomedical field

FINLAND 2016: Stora Enso announces partnership with Elopak for MFC in liquid food packaging

USA 2017: API announces JDA with Birla Carbon for nanocellulose/Carbon

JAPAN 2016: Onkyo launches speakers w/ CNF vibration board

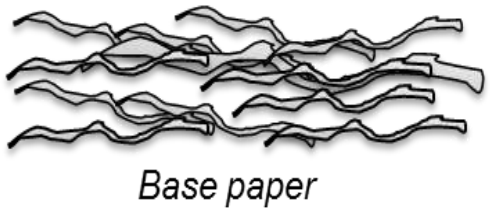
JAPAN 2017: Pione launches headphor w/ CNF vibration board

V.Pylkkanen, American process, Tappi 2017

Paper & Nanocellulose: In Bulk

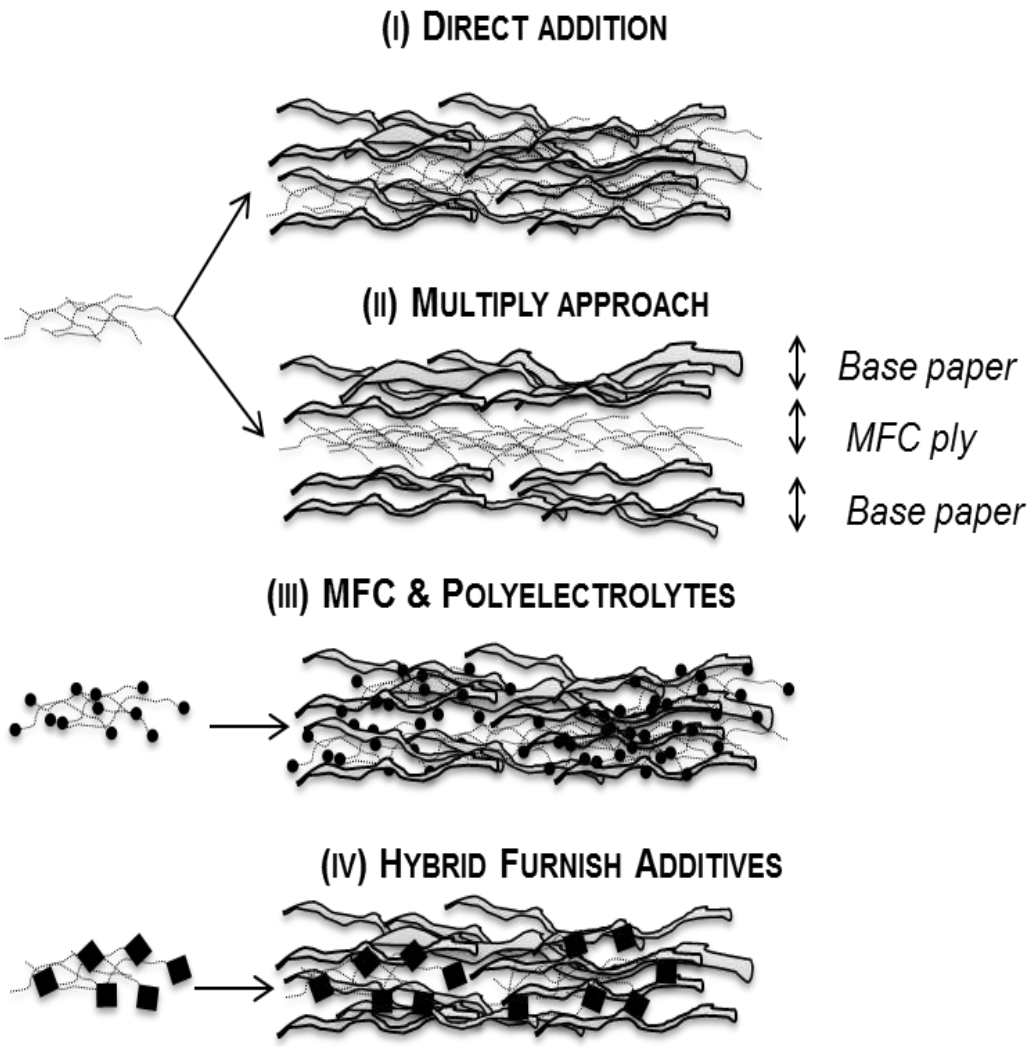
Several strategies

BUT not with NCC



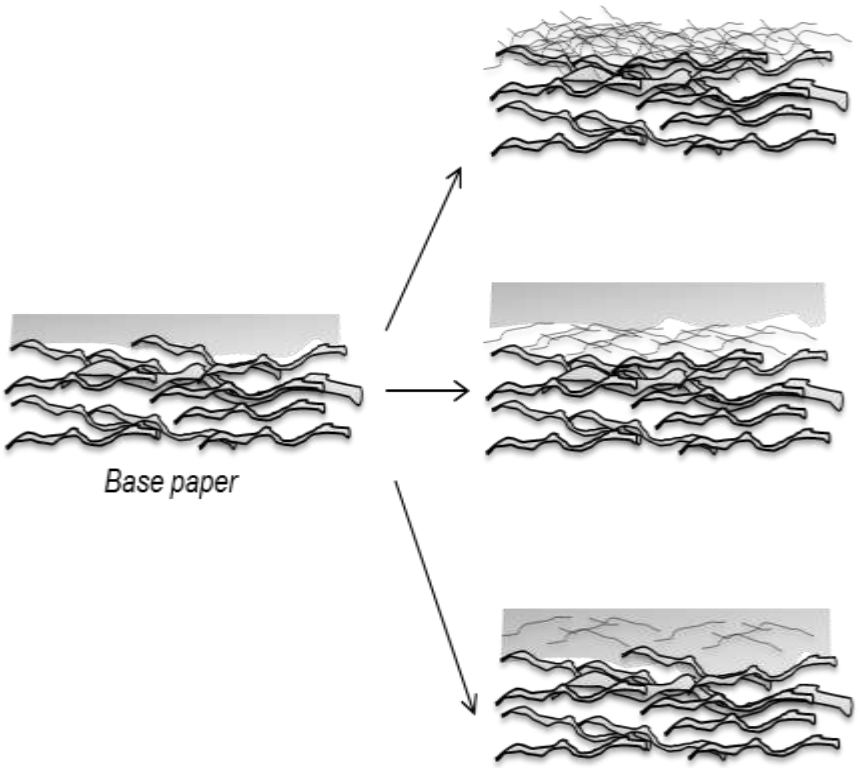
Base paper

« CNF is a dry strength additive
BUT not the magic pill »
T. Lindstrom, Tokyo Paper, 2015



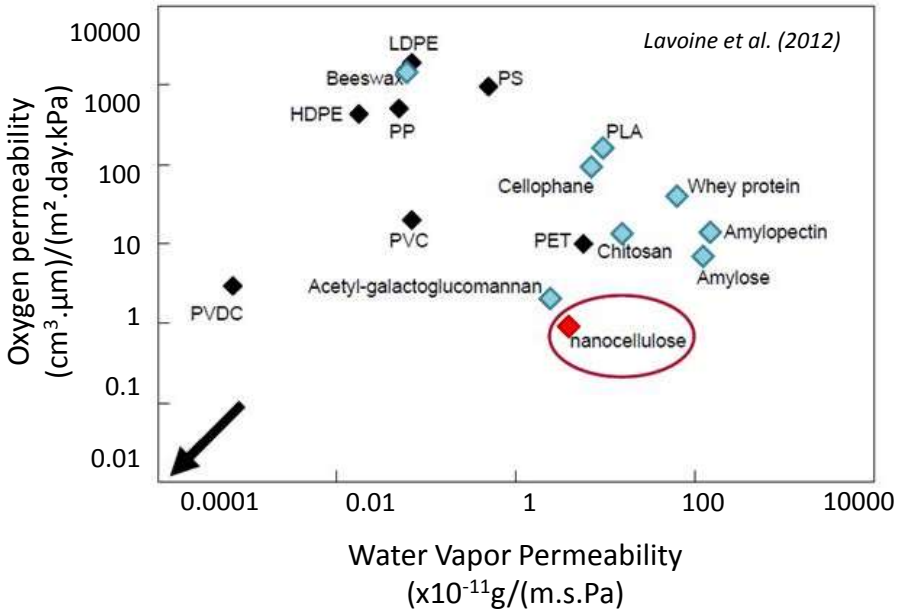
Bardet R.., Bras J., MFC in Paper, 2014, Handbook of Green Materials, K.Oksman,

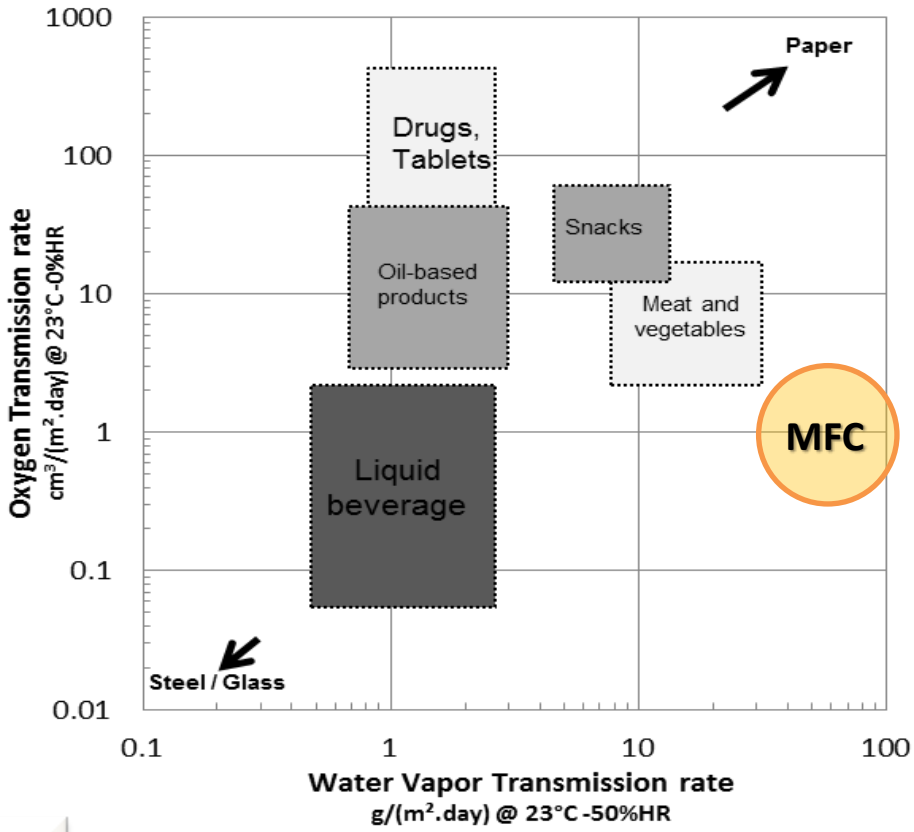
Paper & Nanocellulose : On Surface



Bardet R.., Bras J., MFC in Paper, 2014, Handbook of Green Materials, K.Oksman

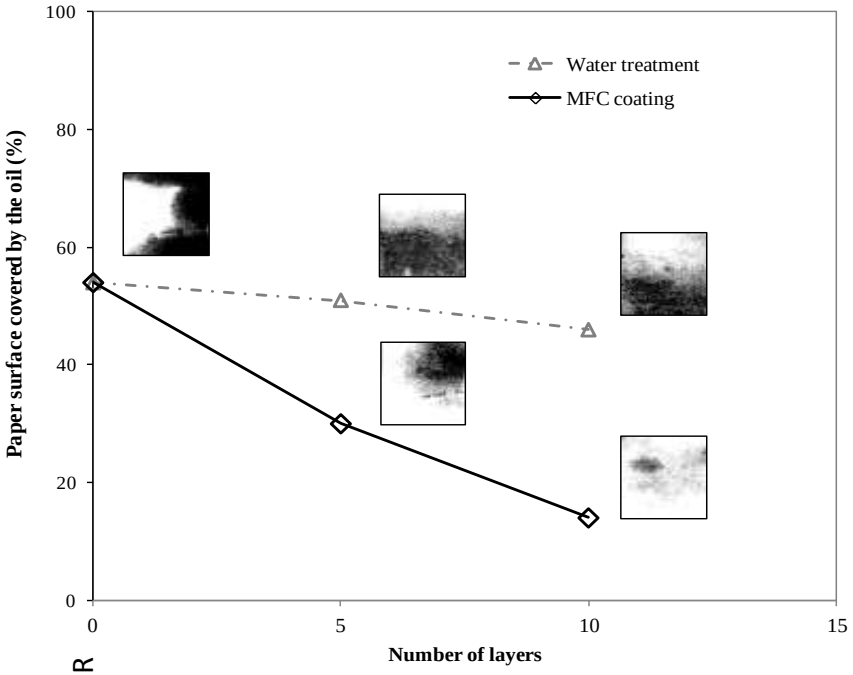
Paper & Nanocellulose : Barrier



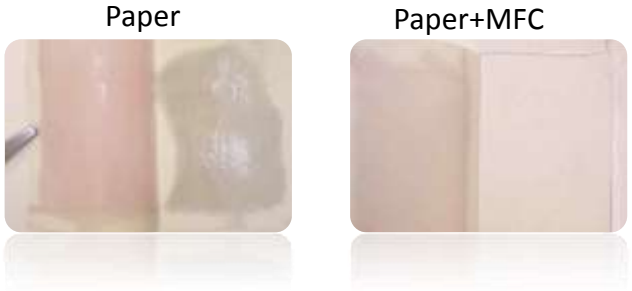


=> CNF = The best bio-based barrier
…at low HR

Paper & Nanocellulose : Barrier



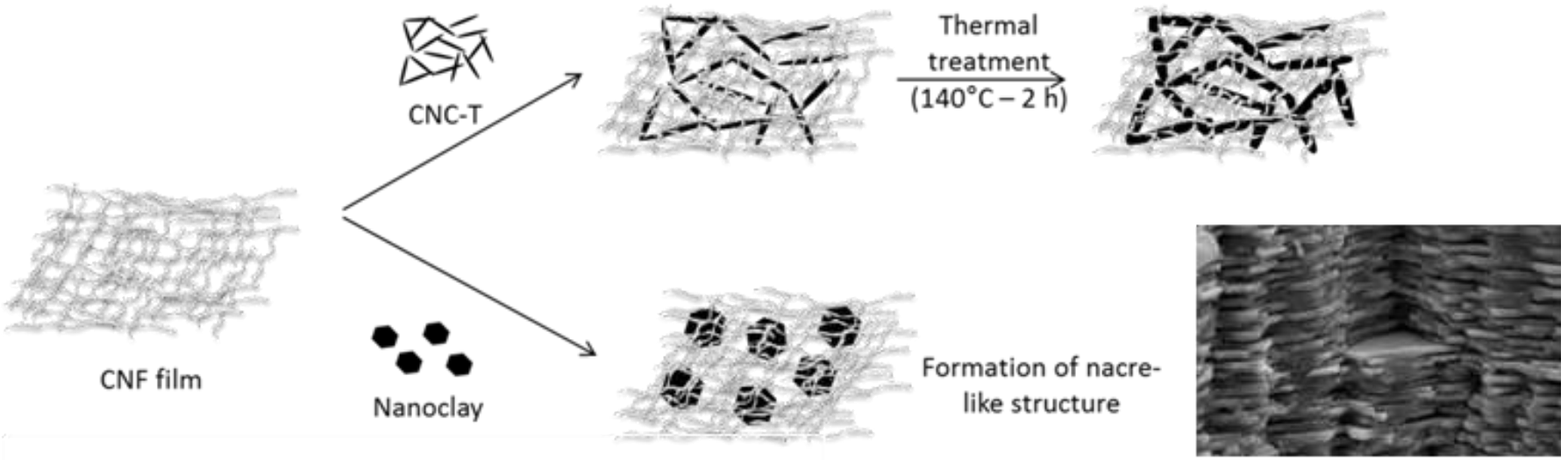
GREASE BARRIER

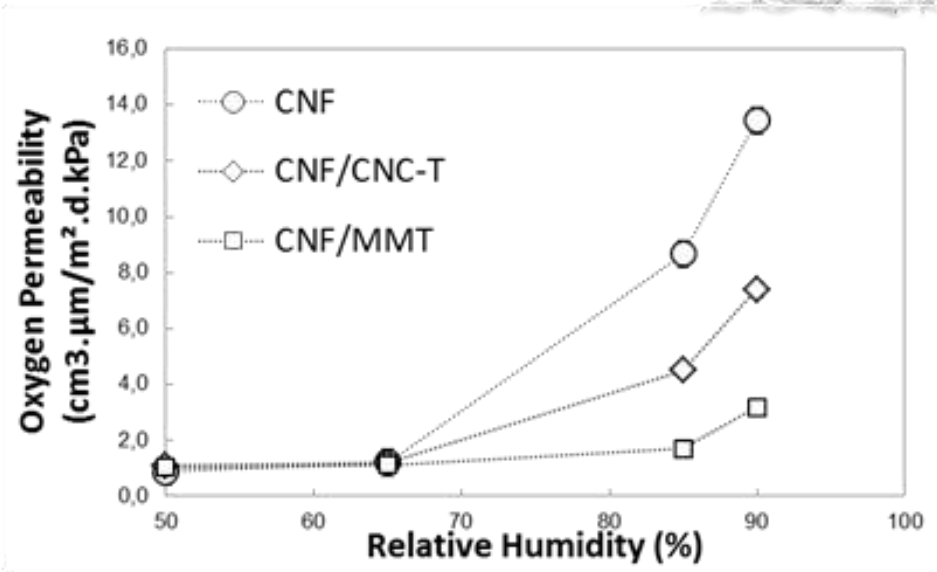


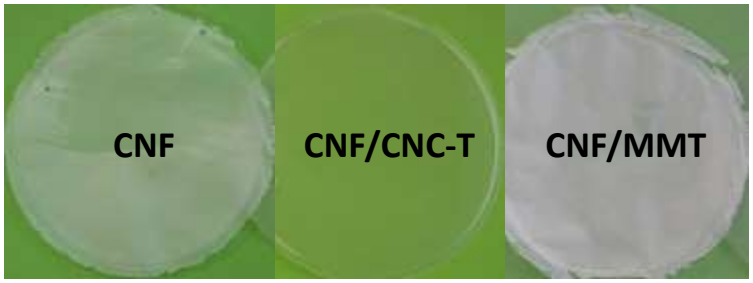
=> Interesting grease barrier of MFC coating

Lavoine N.,et al (2014), J. Mater. Sci., 49, 2879-2893.

Paper & Nanocellulose : Barrier







Bardet, Reverdy, Belgacem, Leirset, Syverud, Bras, J (2015) Cellulose, 22(2), 1227-1241

Nanocellulose : Barrier

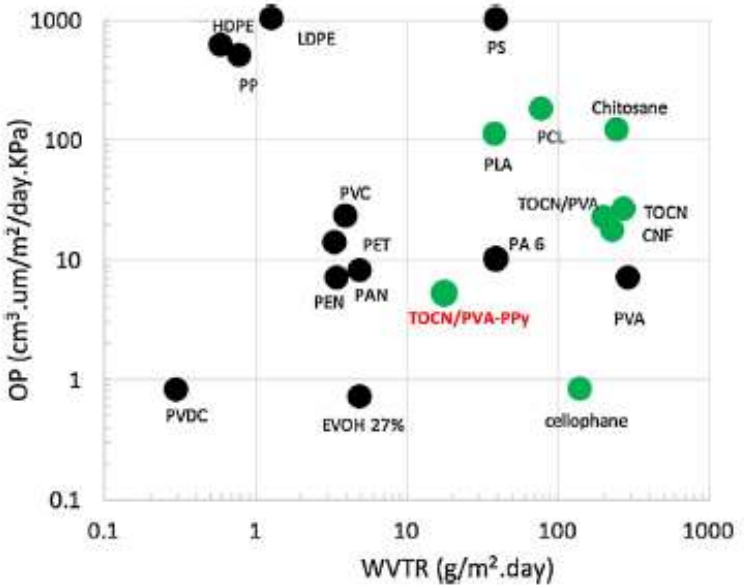
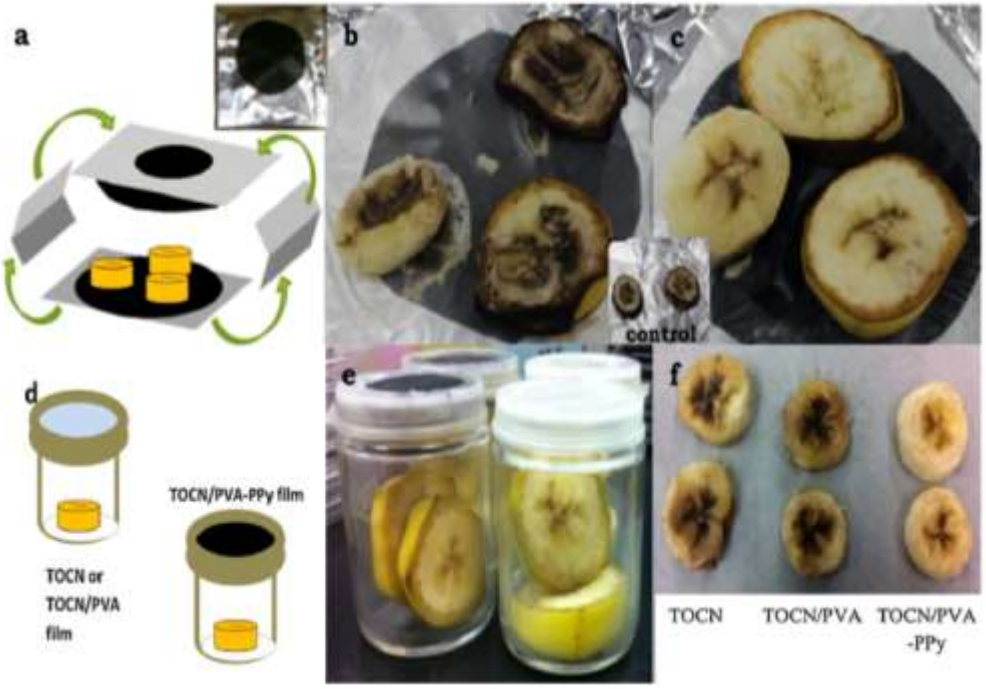


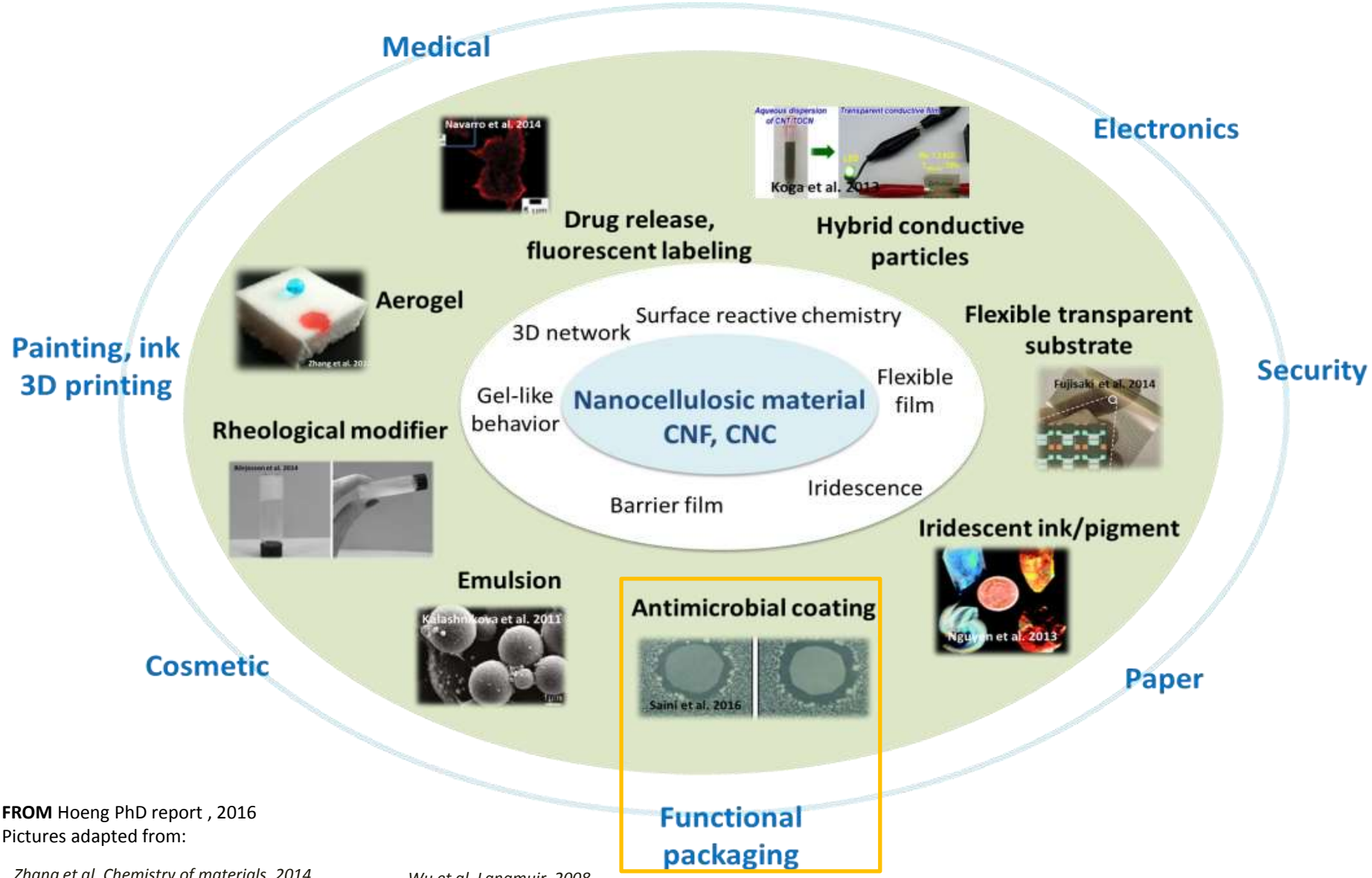
Fig. 4. Oxygen permeability=f (Water Vapor Transmission Rates) – Polymer films compared to TOCN, TOCN/PVA and TOCN/PVA-PPy films. Green points: Biopolymers; Dark points: petroleum polymers.
Adapted from Jester (2005).

Bideau, Bras, Adoui, Loranger, Daneault ; Polypyrrole/nanocellulose composite for food preservation: Barrier and antioxidant characterization, Food Packaging and Shelf Life 12 (2017) 1–8

Perspectives:
Supramolecular system to scavenge molecules, radicals, oxygen



Nanocellulose application



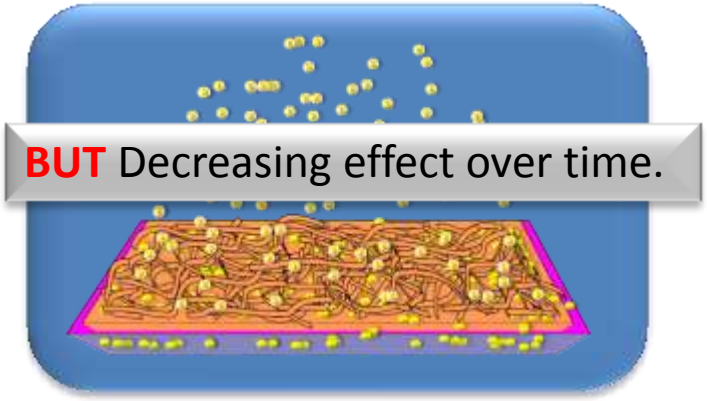
FROM Hoeng PhD report , 2016
Pictures adapted from:

Zhang et al. Chemistry of materials, 2014
Koga et al. NPG Asia, 2014
Saini et al, Applied materials & interface2016

Wu et al. Langmuir, 2008
Moran-Mirabal , Cellulose: fundamenbtal aspect, Chapter I, 2013
PFI, Ching-Carrasco

Antimicrobial packaging

(i) Incorporation into CNF network

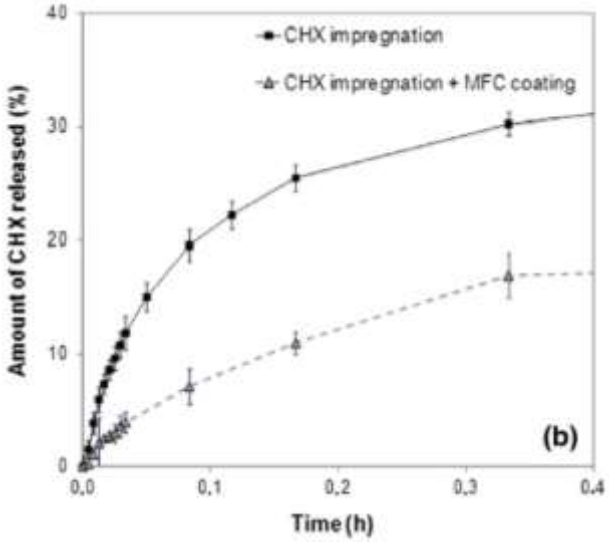


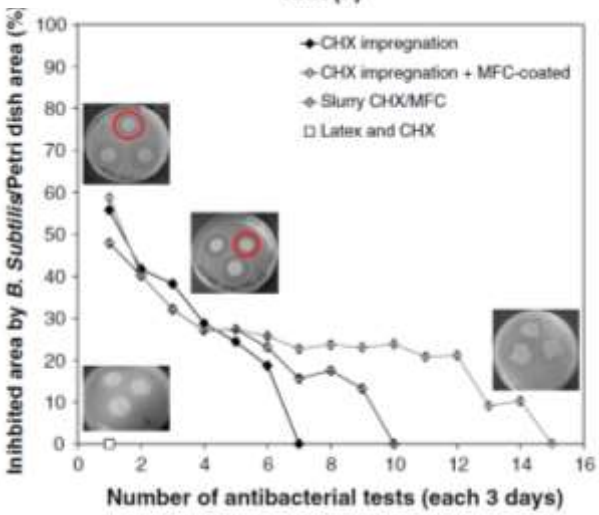
Release mechanism

- ✓ Antimicrobial agents incorporated in the packaging.
- ✓ Migrate into food through diffusioning and partitioning.
- ✓ Very positive impact of MFC for release monitoring

=> prolonged antimicrobial activity whatever molecules

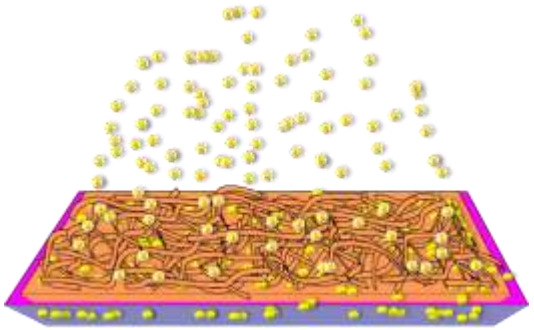
Lavoine, N.; Desloges, I.; Sillard, C.; Bras, J. (2014)
Controlled release and long-term antibacterial activity of chlorhexidine digluconate through the nanoporous network of microfibrillated cellulose, Cellulose, 21(6), 4429-4442.



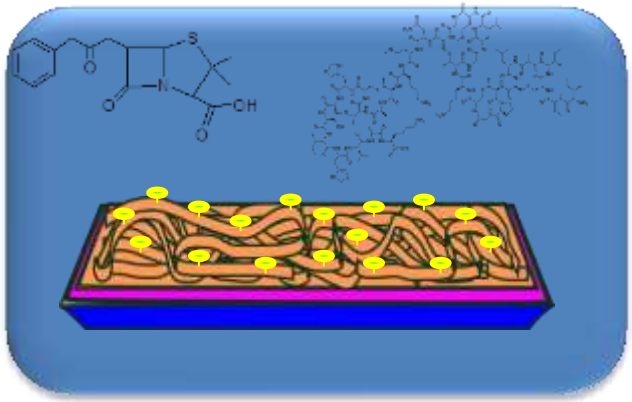


Antimicrobial packaging

(i) Incorporation into CNF network



(ii) Immobilisation onto CNF



Release mechanism

- ✓ Antimicrobial agents incorporated in the packaging.
- ✓ Migrate into food through diffusioning and partitioning.
- ✓ Decreasing effect over time.

Contact mechanism

- ✓ Antimicrobial agents immobilized on the packaging.
- ✓ Microbial suppression at the contact surface without diffusion.
- ✓ Prolong effect.

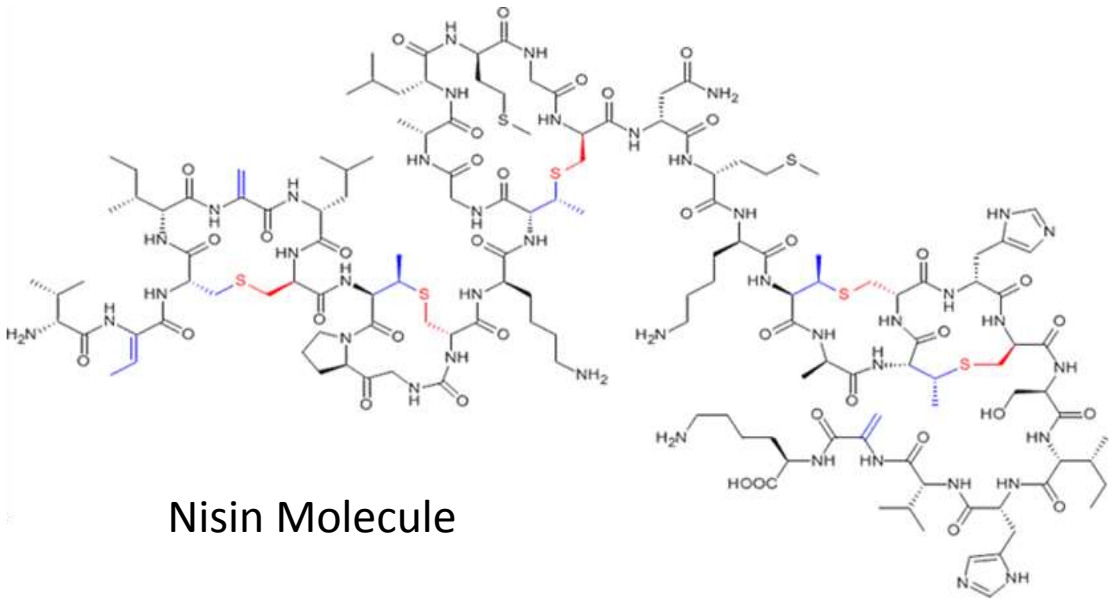
- Saini, ; Belgacem, N; Mendes, J; Elegir, G; Bras, J
Contact Antimicrobial Surface Obtained by Chemical Grafting of Microfibrillated Cellulose in Aqueous Solution Limiting Antibiotic Release,
ACS Applied Materials & Interfaces (2015), 7(32), 18076-18085

-Saini, M. N. Belgacem, K. Missoum, J. Bras,
Natural active molecule chemical grafting on the surface of microfibrillated cellulose for fabrication of contact active antimicrobial surfaces, Industrial Crops and Products (2015), Accepted-in press.

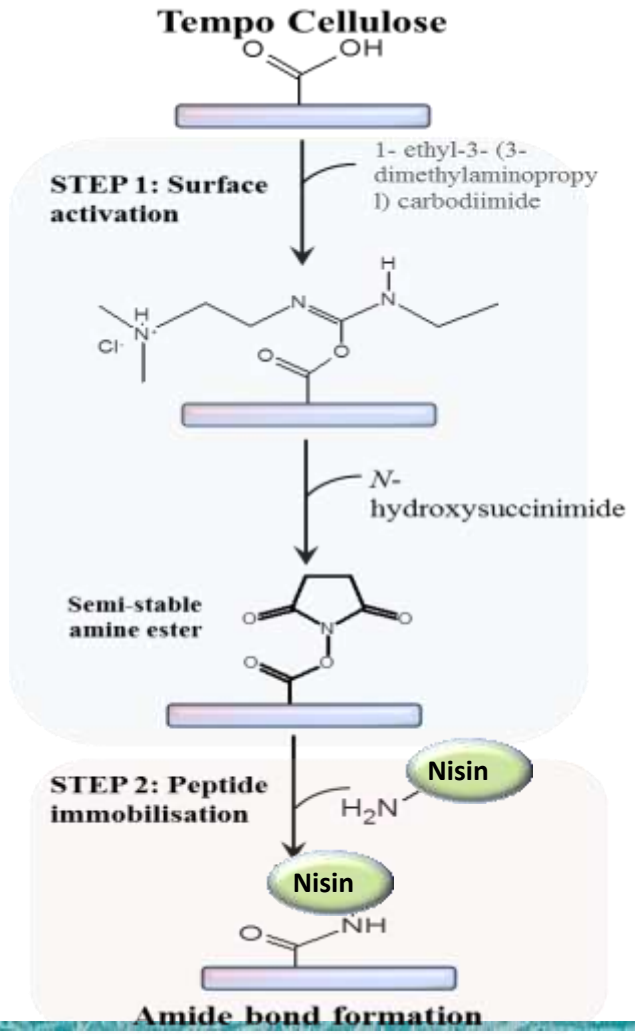
CNF functionnalization : post-treatment

Globally, 3, 51,000 people die every year due to the food poisoning
Antimicrobials in bulk is unable to target the food surface

Nisin: approved in 40 countries over 50 years.
Allowed in canned fruits, vegetables, and cheese.

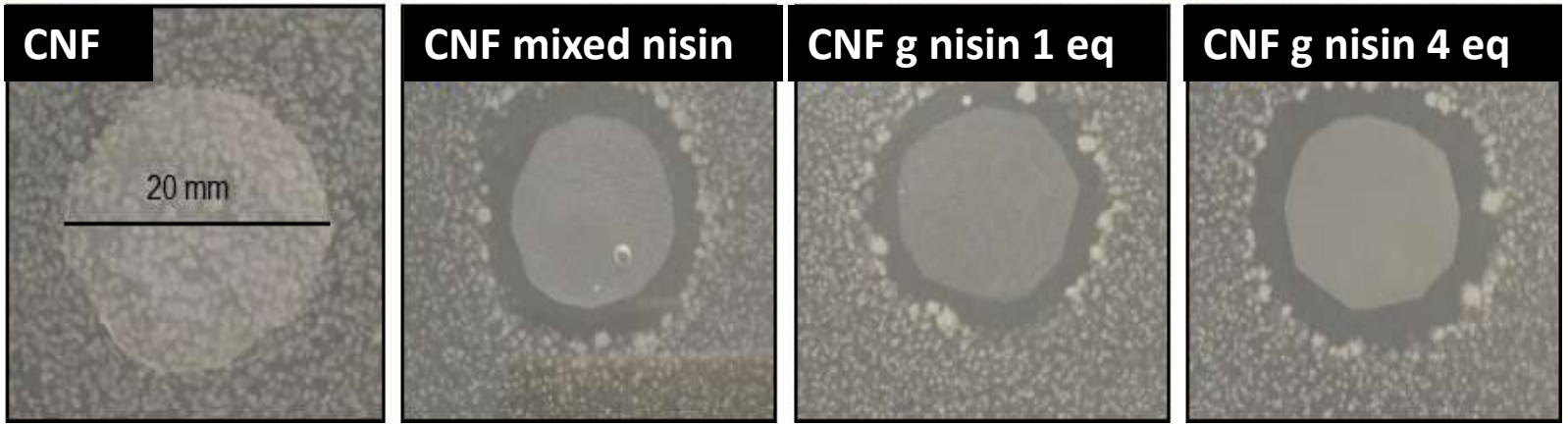


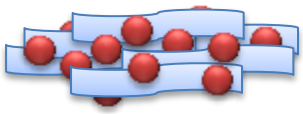
Nisin Molecule



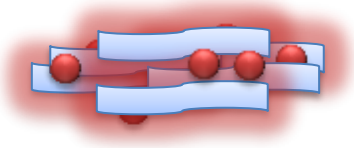
Saini, S; Sillard, C; Belgacem, Bras, J , Nisin anchored cellulose nanofibers for long term antimicrobial active food packaging , RSC Advances (2016), 6(15), 12422-12430

CNF functionnalization : post-treatment





CNF film mixed with Nisin

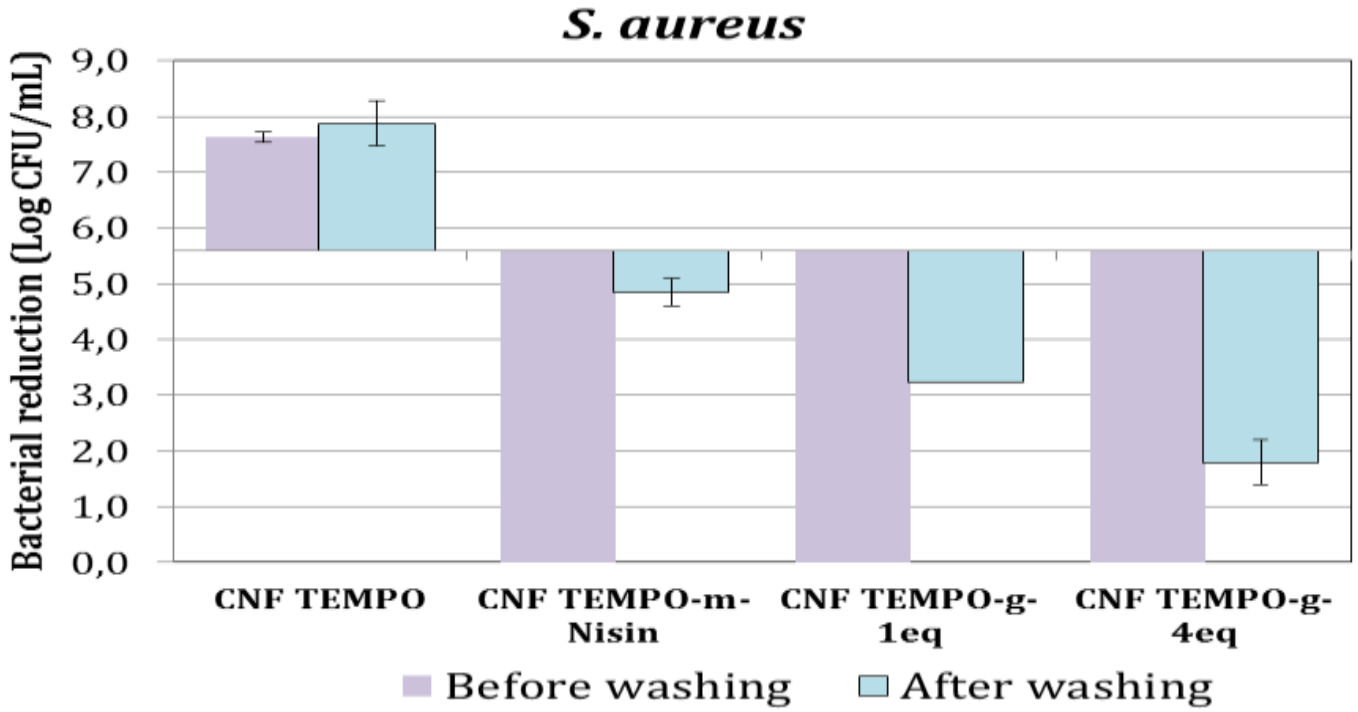


CNF film grafted with Nisin

- Zone of inhibition showed presence of non-covalent boned nisin
- uncontrolled and non-covalent immobilization of peptide forms an unstable layer

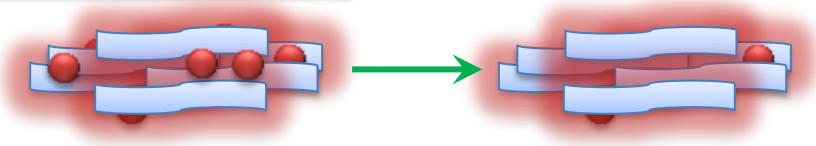
Saini, S; Sillard, C; Belgacem, Bras, J , Nisin anchored cellulose nanofibers for long term antimicrobial active food packaging , RSC Advances (2016), 6(15), 12422-12430

CNF functionnalization : post-treatment



Grafting more efficient for stronger bacteria

CNF film mixed with Nisin



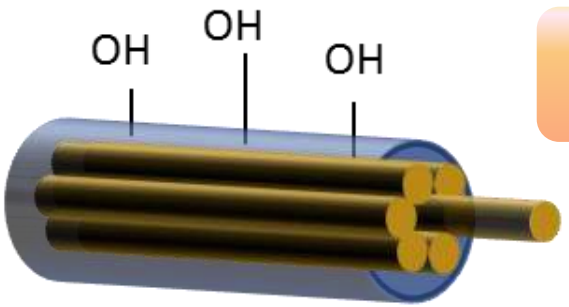
CNF film grafted with Nisin

After washing for 48 hours, high bacterial killing (60% CNF Tempo-g-1-eq and 78% CNF Tempo-g-4eq) in comparison with 40% killing effect by CNF Tempo-m-Nisin.

Saini, S; Sillard, C; Belgacem, Bras, J , Nisin anchored cellulose nanofibers for long term antimicrobial active food packaging , RSC Advances (2016), 6(15), 12422-12430

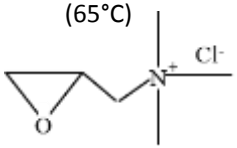
CNF Pre-treatment

2,3-epoxypropyl trimethylammonium chloride (EPTMAC)

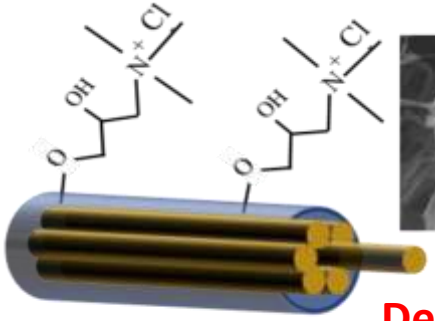


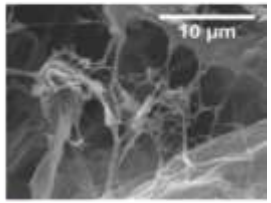
Step 1: Optimisation of pretreatment for different DS

NaOH, EPTMAC
(65°C)



Cationized cellulose



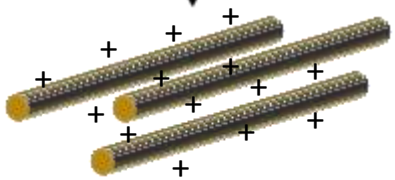


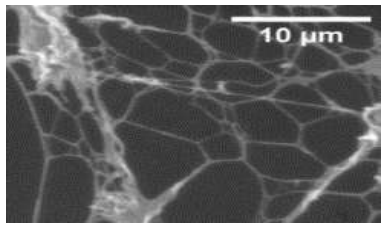
Degree of substitution

Masuko®Grinder

Fibrillation of cationized cellulose

Energy consumption





Morphology

Cationized nanofibrils

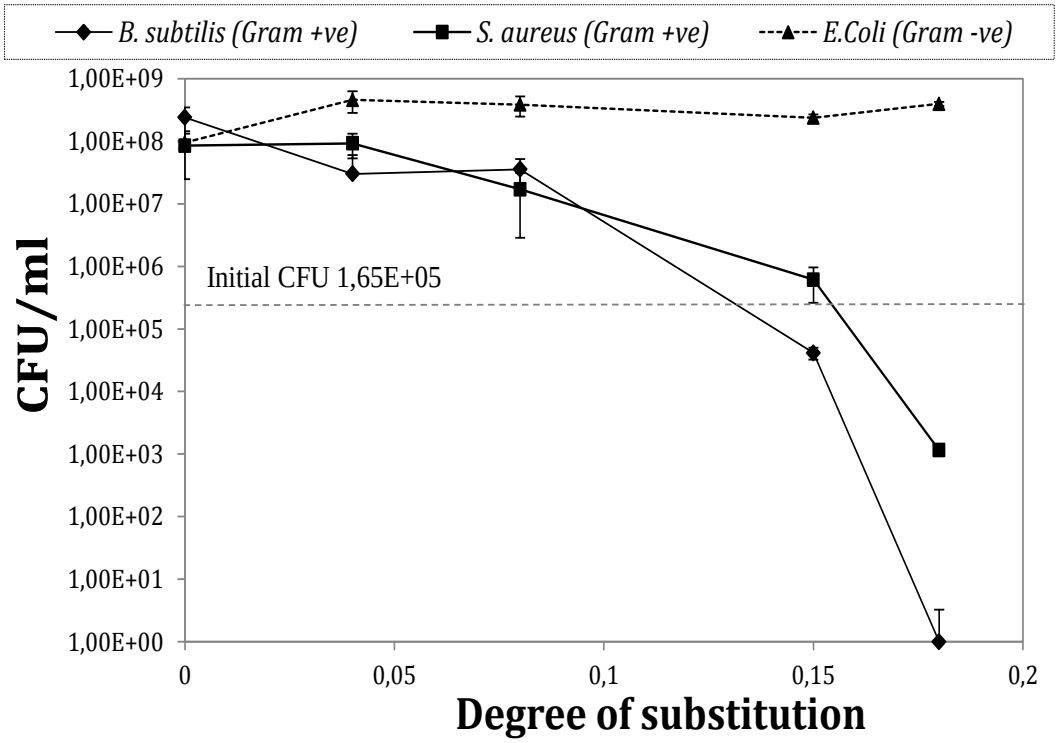
Activity against Gram +ve and Gram –ve bacteria

Qualitative and quantitative antimicrobial activity

Step 2: Antibacterial activity evaluation of cationic CNF

Surface cationized cellulose nanofibrils for the production of contact active antimicrobial surfaces , S. Saini, C. Yucel-Falco, M. N. Belgacem, J. Bras Carbohydrate polymers (2015), 135, pp 239-247.

Antimicrobial packaging

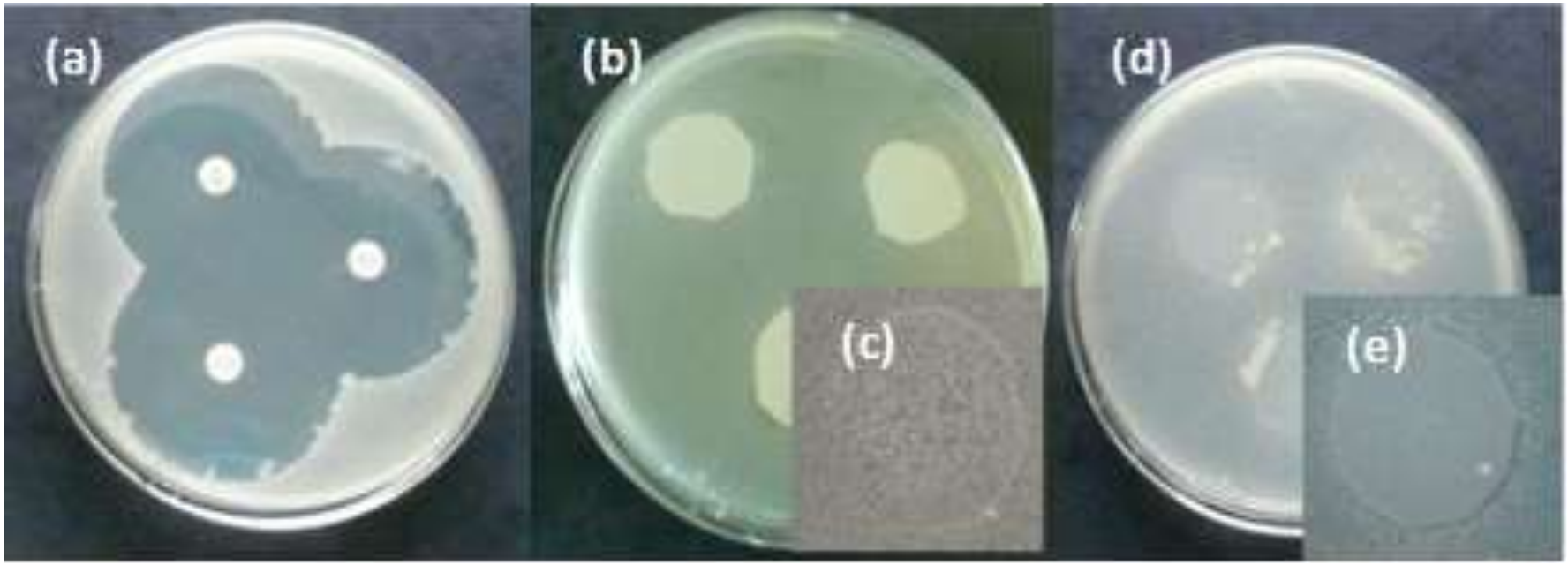


- ✓ CATMFC DS=0,04: Antimicrobial agents lower than Minimum inhibitory concentration.
- ✓ CATMFC DS=0,18: 3 log reduction with high SD => samples are heterogenous.
- ✓ E.coli – need to increase degree of substitution.

S. Saini, C. Yucel-Falco, M. N. Belgacem, J. Bras, « Surface cationized cellulose nanofibrils for the production of contact active antimicrobial surfaces », Carbohydrate polymers (2015), 135, pp 239-247.

Antimicrobial packaging

Bacteria: *Bacillus subtilis (Level 1) Gram +ve*



PENICILLIN: Positive Control

ENZY MFC: Negative Control

CAT-MFC DS= 0.18

- No Zone of inhibtion: No free EPTMAC leaching
- Antimicrobial by contact

Industrial Pilot trial at Multipackaging Solutions

Multi Packaging Solutions

Towards demonstrator

FP1405 COST action

ActInPak

Nanocellulose in transparent conductive inks

Transparent conductive layer using nanocellulose-silver nanowires suspension

Screen printing
High viscosity inks

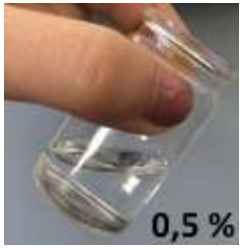
CNF gel

CNF-silver nanowires stable suspension

Transparent conductive patterns / films

Lab-scale bar coating
Medium viscosity

Easy processing
Scalable process



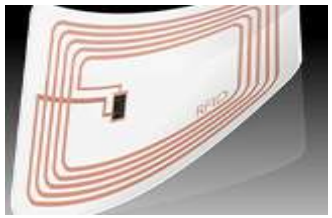
CNF liquid suspension

Poly-Ink

Poly-Ink
Inkjet the future...

www.poly-ink.fr

Poly-Ink develops and markets functional ink implemented by low viscosities printing techniques


3 products range

Transparent and conductive inks

Poly-Ink HC Carbon nanotubes (CNT) based inks – ITO replacement

PolyBioWire Silver nanowires based inks – ITO replacement

Conductive ink

PolySilver Silver nanoparticles based inks

Multi-substrate printing

PolyPrimer Tuned surface properties for various substrates to printed electronics requirements

CNF-silver nanowires coating	
R_{sh} (Ω/□)	13 ± 3
$T_{550\ nm}$% (%)	90.1 ± 0.5
ΔL*	3.1 ± 1.8

Application and up-scaling of silver nanowires screen printing ink

Up-scaled trials and electro-luminescent application

Collaboration University of Pardubice- Czech Republic (ActInPak COST action) + Industrial partner

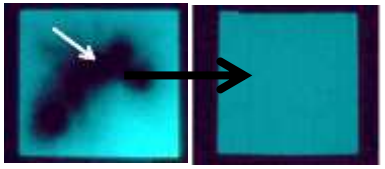
CNF- silver nanowires screen printing ink

STEP 1
Large scale ink preparation

- ✓ Easy preparation (mixing + mechanical agitation)
- ✓ Adaptable to large scale prepation

STEP 2
Opto-electronic devices design

- ✓ Working opto-electrical devices
- ▪ Issues of chemical stability

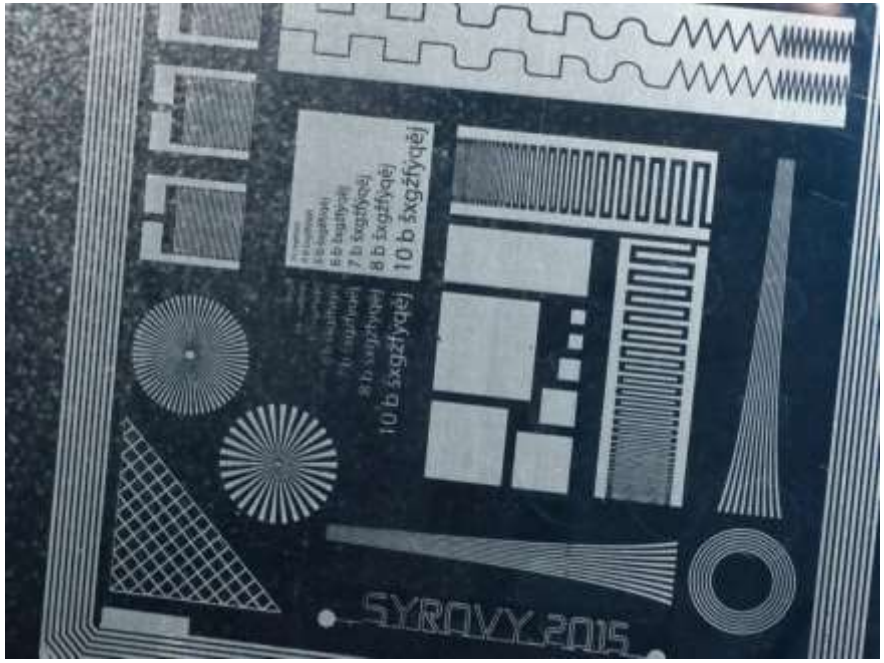


STEP 3
Industrial roll to roll printing

- ✓ Effective roll to roll printing
- ▪ Rheology is not optimal → viscous
- ▪ Clogging of the mesh → drying rate

PolyBioWire ®– Screen printing grade

Printing of PolyBioWire – Screen printing grade



PolyBioWire SP® film	
Substrate	PET
R_{sh} (Ω/□)*	25 ± 3
T% (%)*	83 ± 0,5
ΔL*	3,2 ± 0,7
Δa*	1,4 ± 0,3
Δb*	6,2 ± 0,4

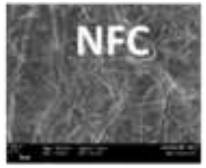
**Best compromise in opto-electrical properties, transparency without substrate*

- Low resistance
- High transmittance
- Good patterning

S2PAck project 2017-2020

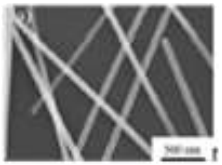
MATERIALS

Nanocelluloses
(Stabilizing, Film forming, Entangled network, Functionalization, etc.)

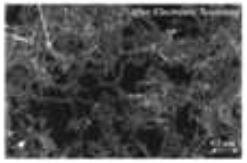


Functional materials

Silver nanowires



Carbon nanotubes



Surface treatment
Coating processes

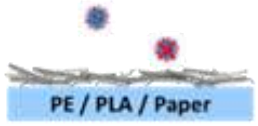
Slot die

Bar coating

Spray

Heliogravure

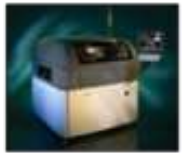
Sensors
(microbial breakdown, gaz, T°, temper detection)



Antimicrobial active layer
Contact killing action

Localized treatment
Printing processes

Inkjet



Screen-printing

Flexography

Applications
SAFE & SMART packaging

Medical packaging

Food packaging

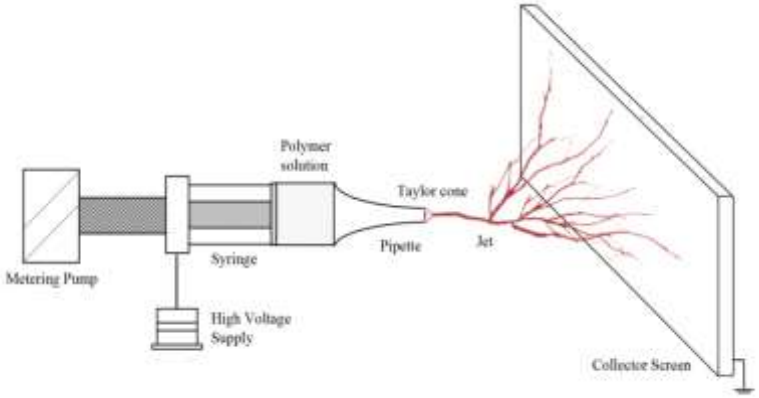
Smart detection label

UNSAFE

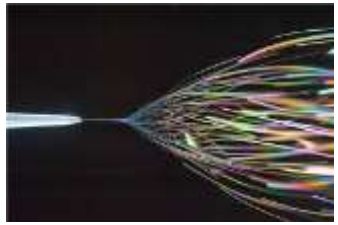
OUTLINE

- NEW SOLUTIONS IN MATERIALS
  - Antimicrobial Peptides for Bioactive Packaging
  - Cellulose nanofibers (CNF) as a new opportunity
- NEW SOLUTIONS IN PROCESSES
  - Encapsulation systems in the packaging material
  - Electrospinning for active materials
- NEW CONCEPTS IN ACTIVE PACKAGING
  - Bionanocomposites for active packaging

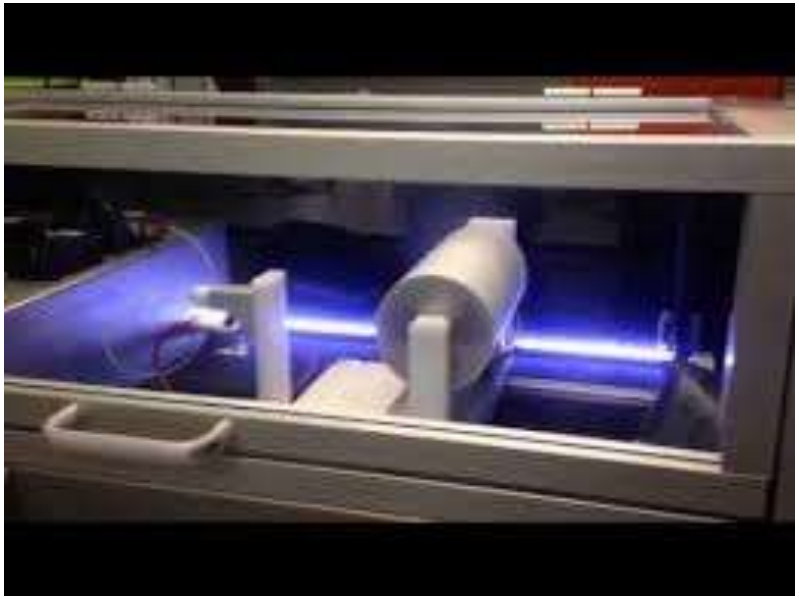
Electrospinning



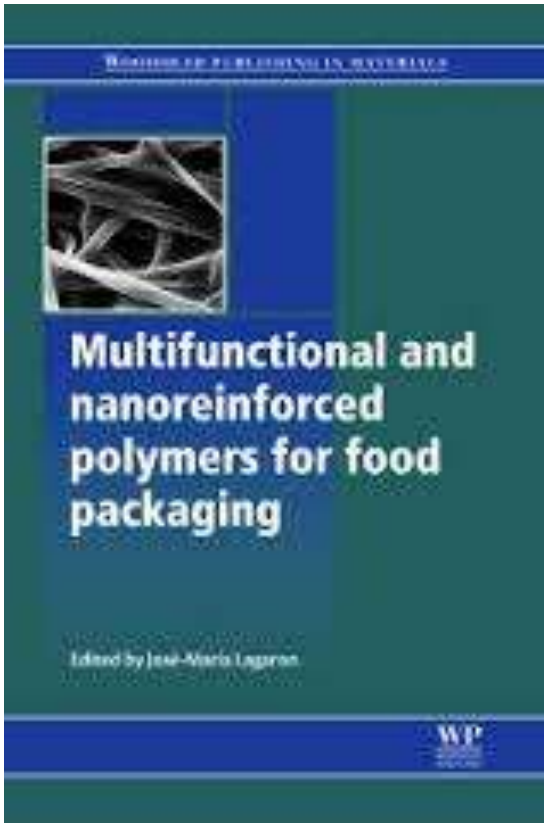
BioInicia

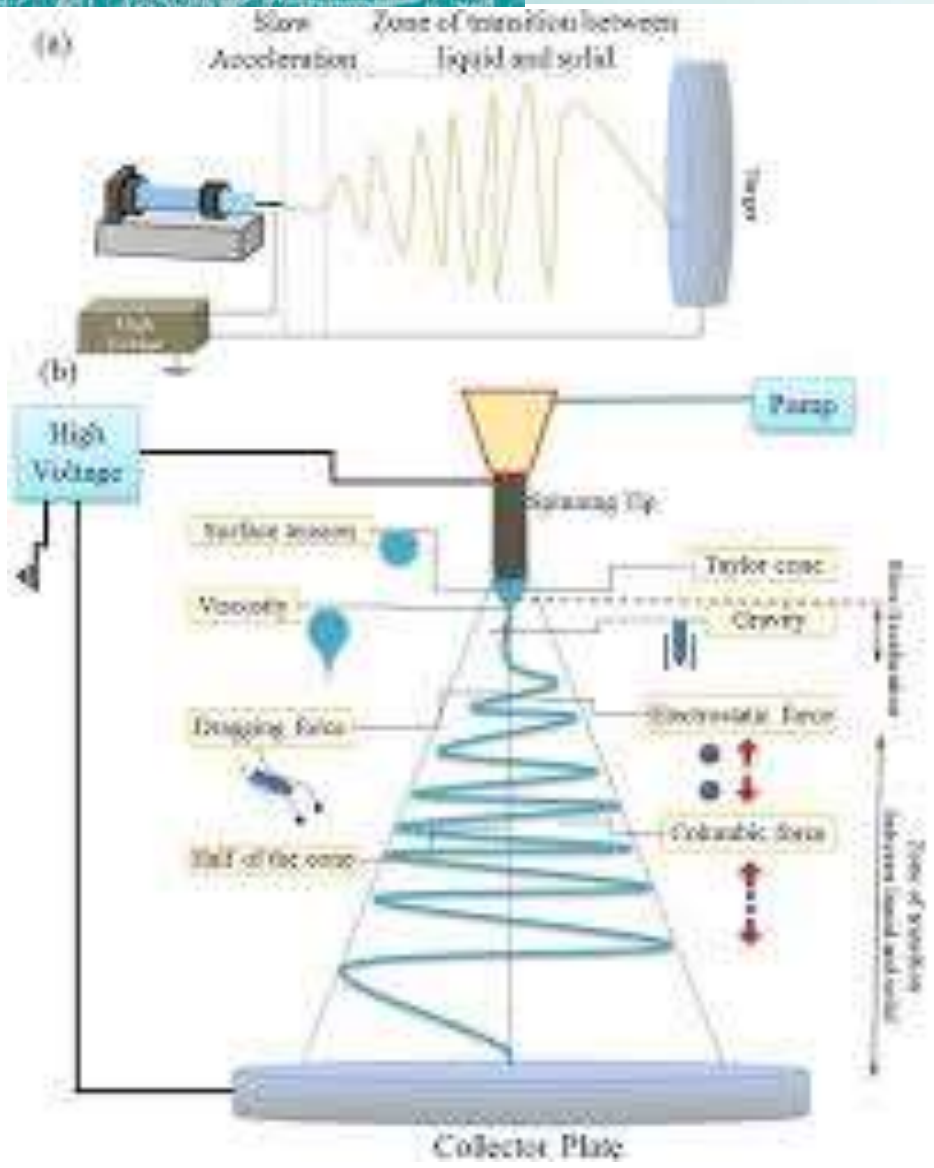


2010's: From Labscale to Industry

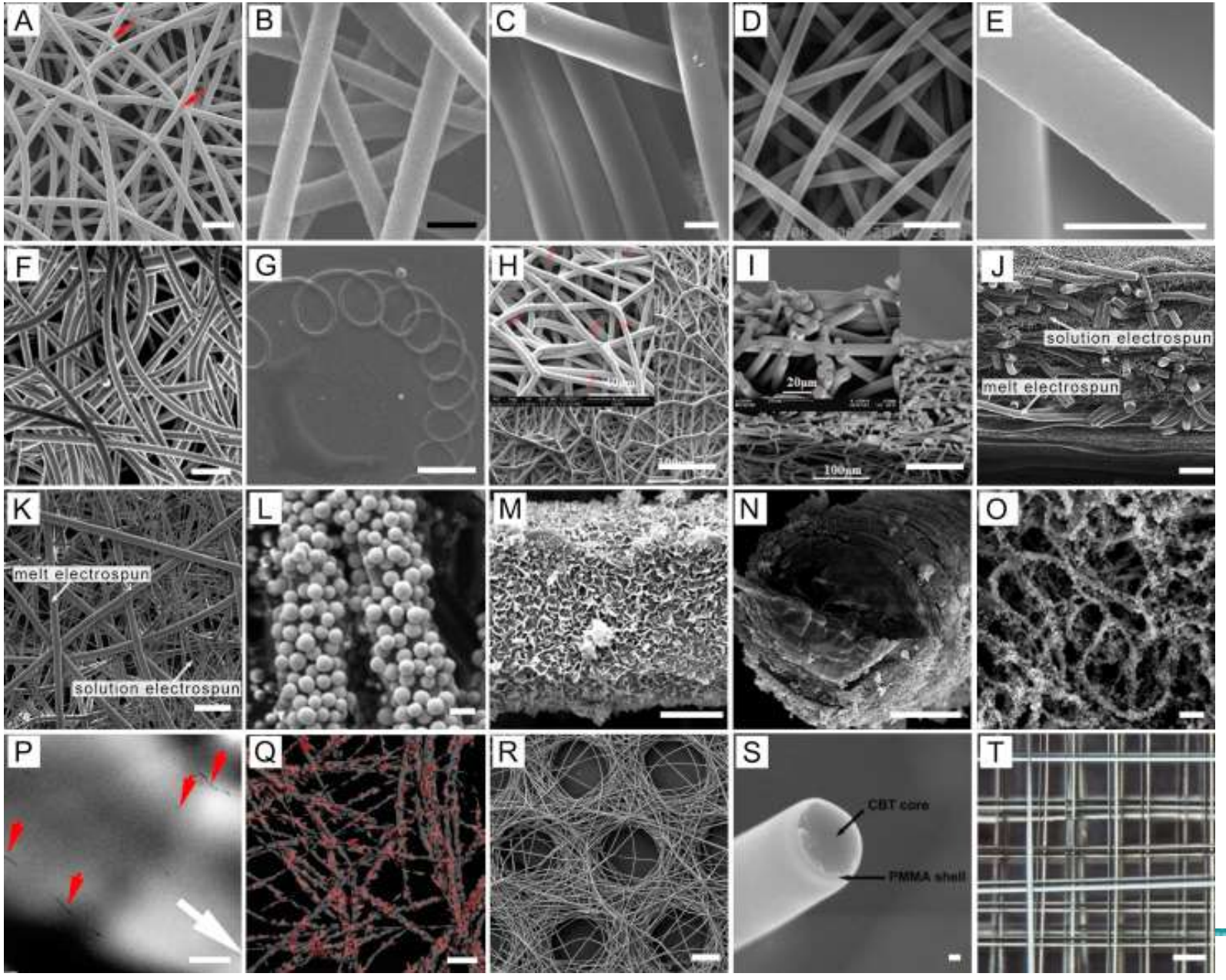


Electrospinning



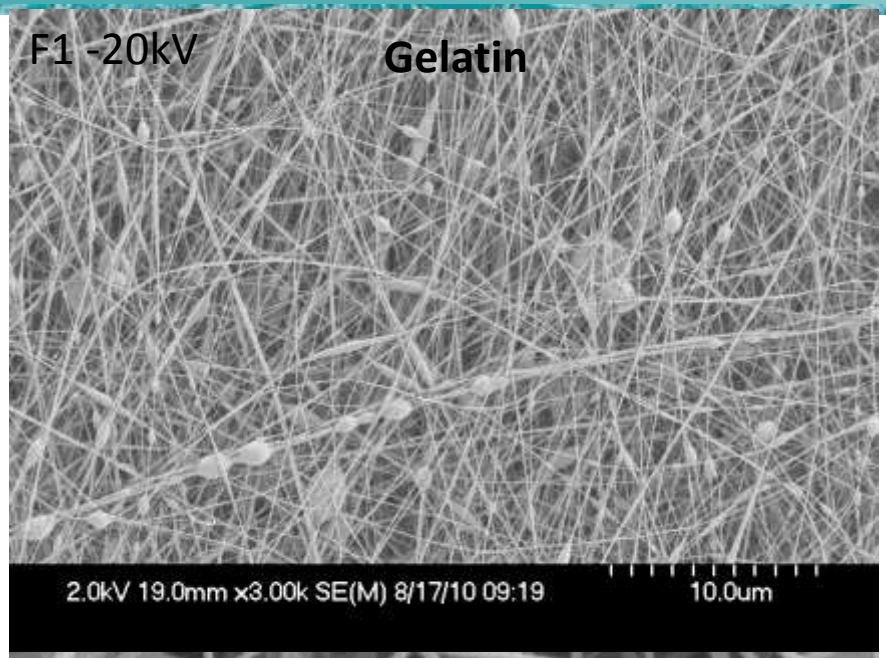


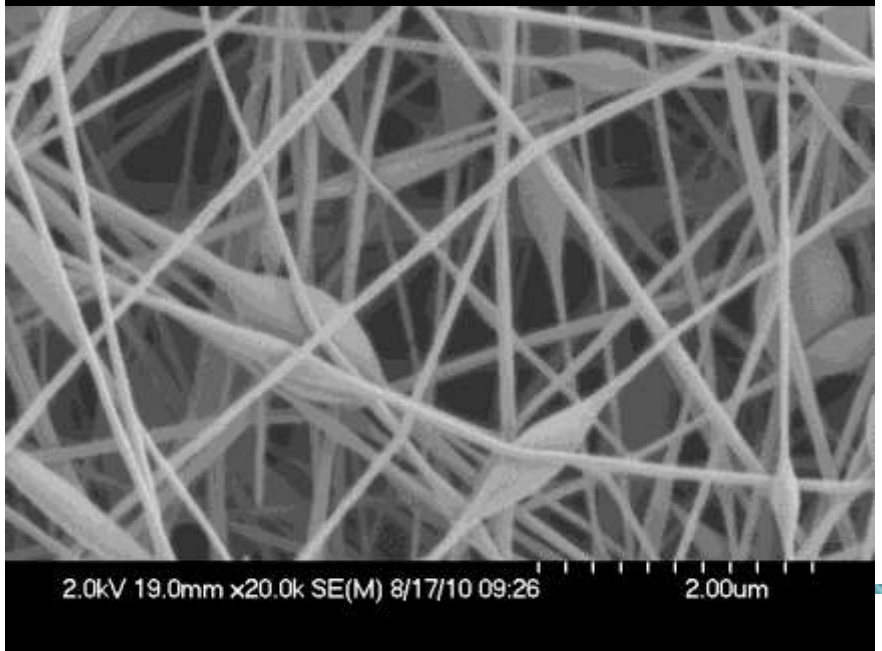
Electrospinning



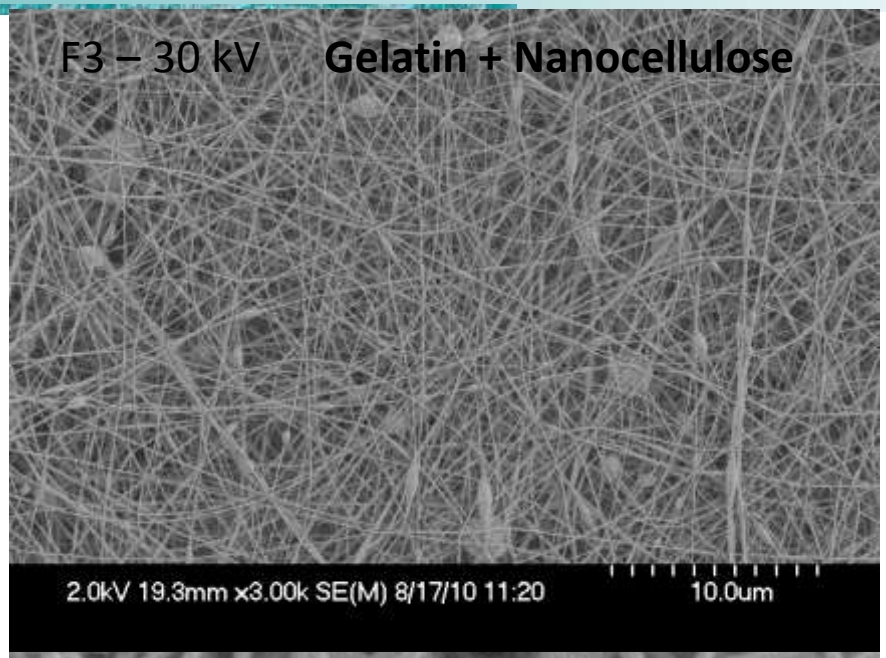
Electrospinning

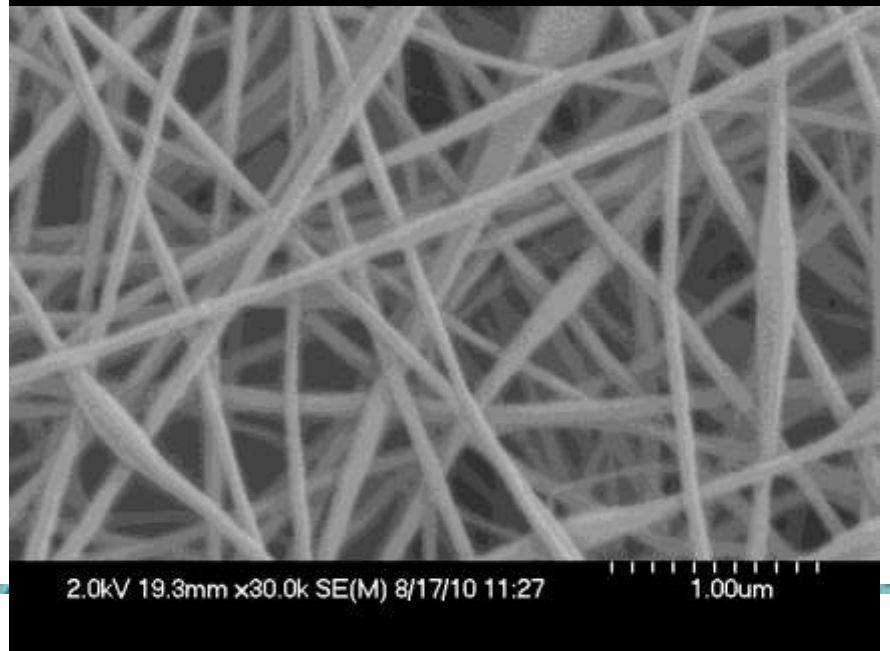
F1 -20kV **Gelatin**





F3 – 30 kV **Gelatin + Nanocellulose**

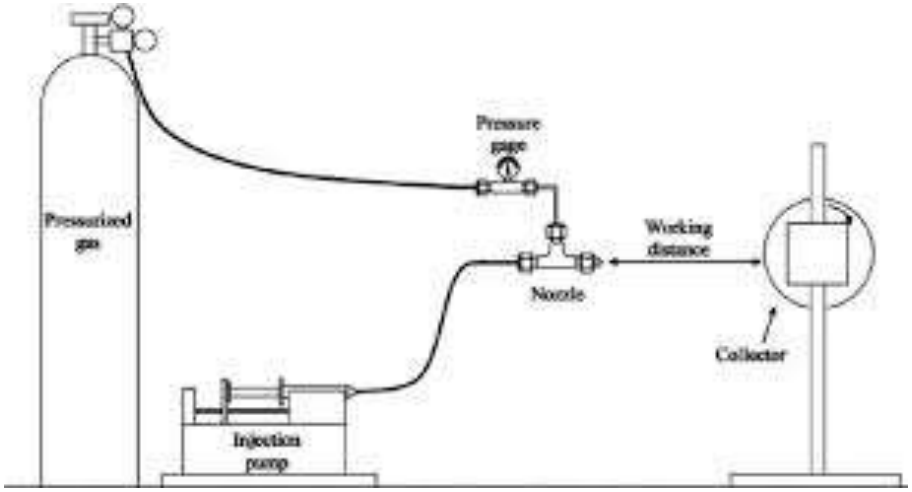


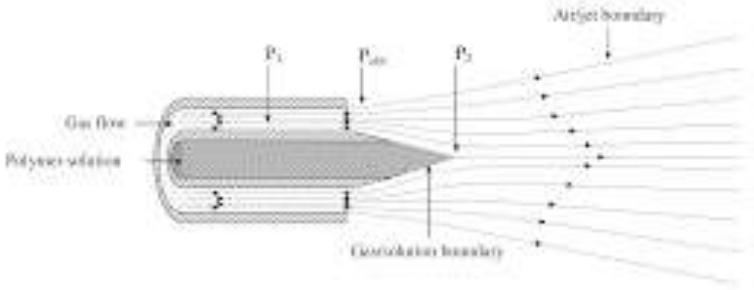


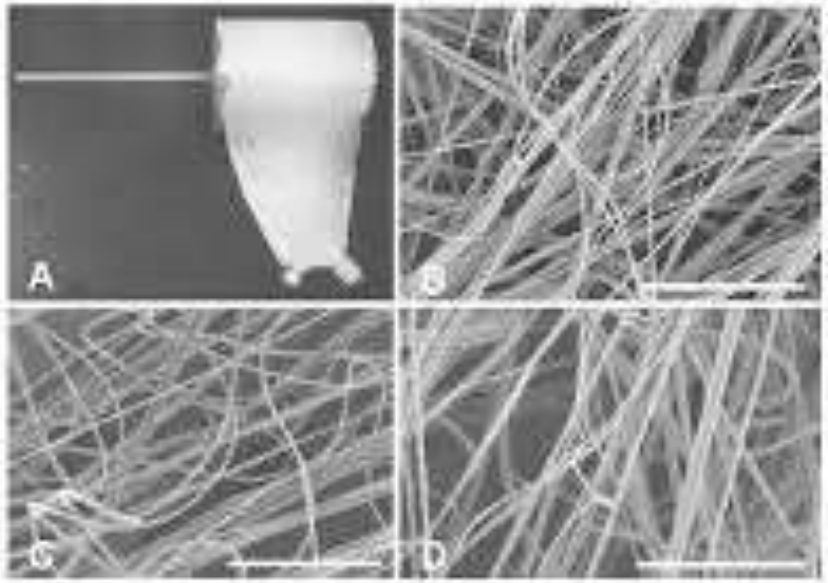
Electrospinning vs Solution Blow spinning

Solution Blow Spinning =

Electro spinning without electricity

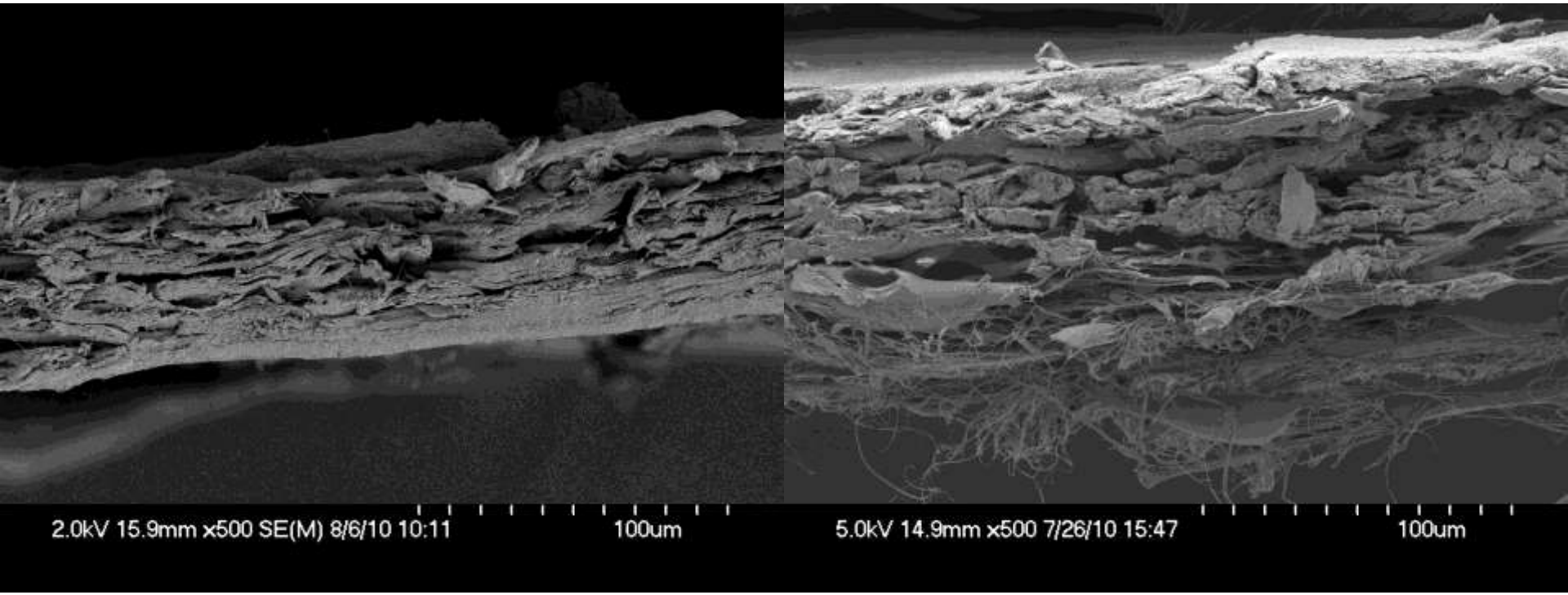






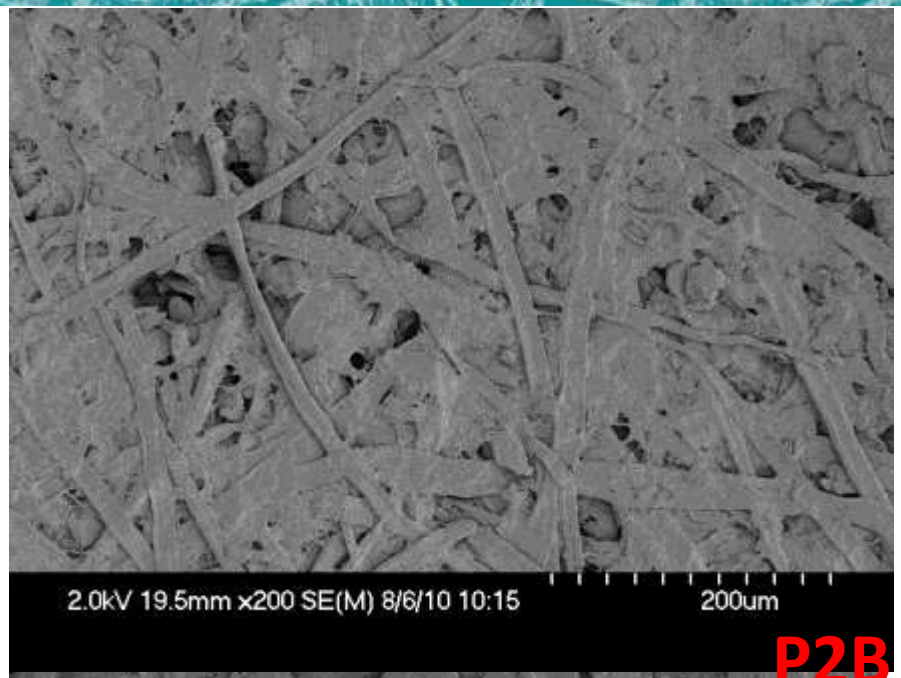
Solution Blow spinning

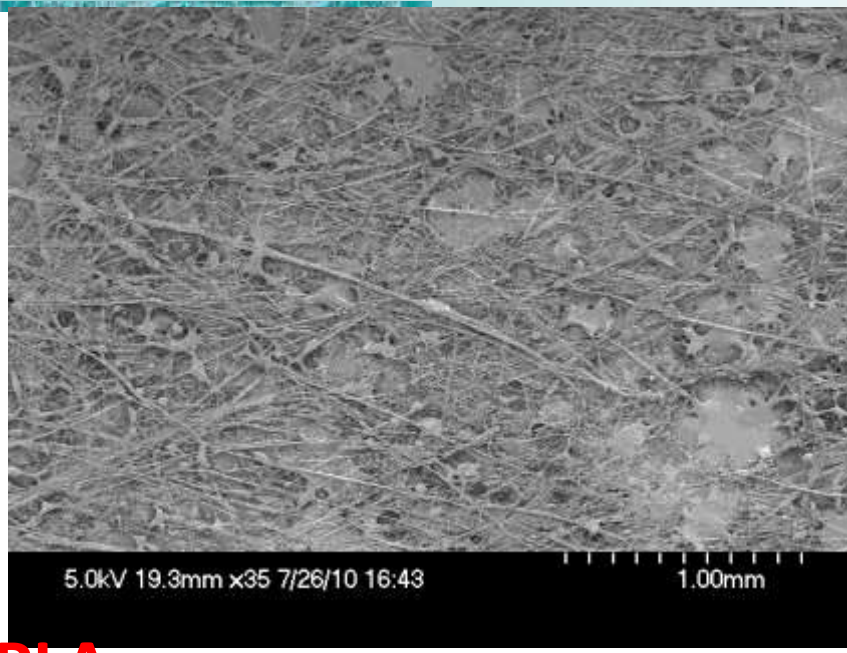
. Pre-trials on paper: sticking possibility



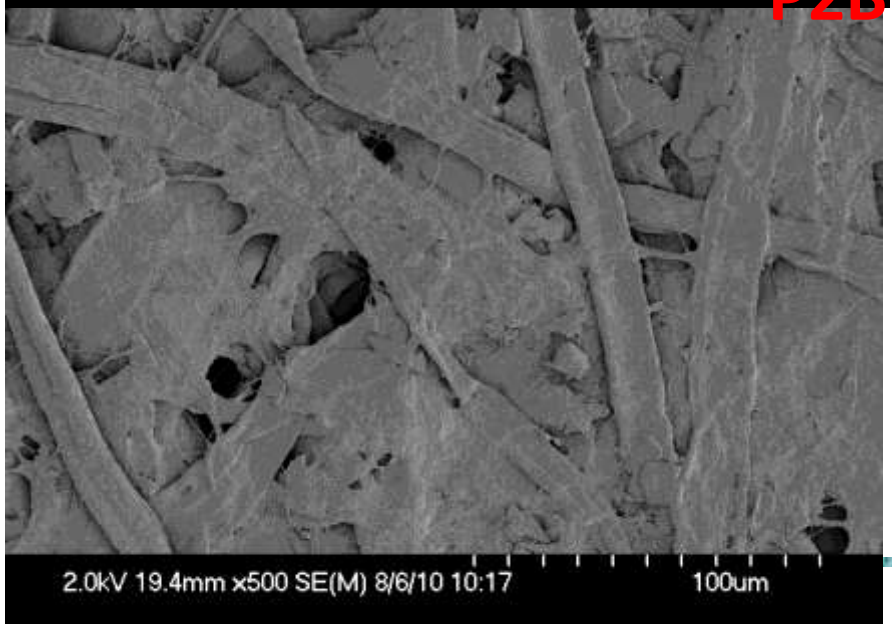
SBS of PLA

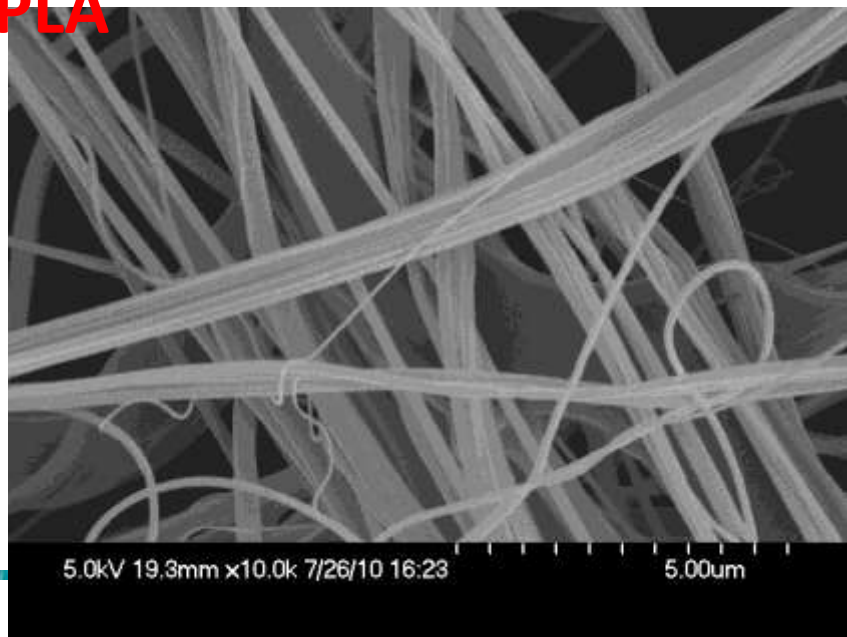
Solution Blow spinning



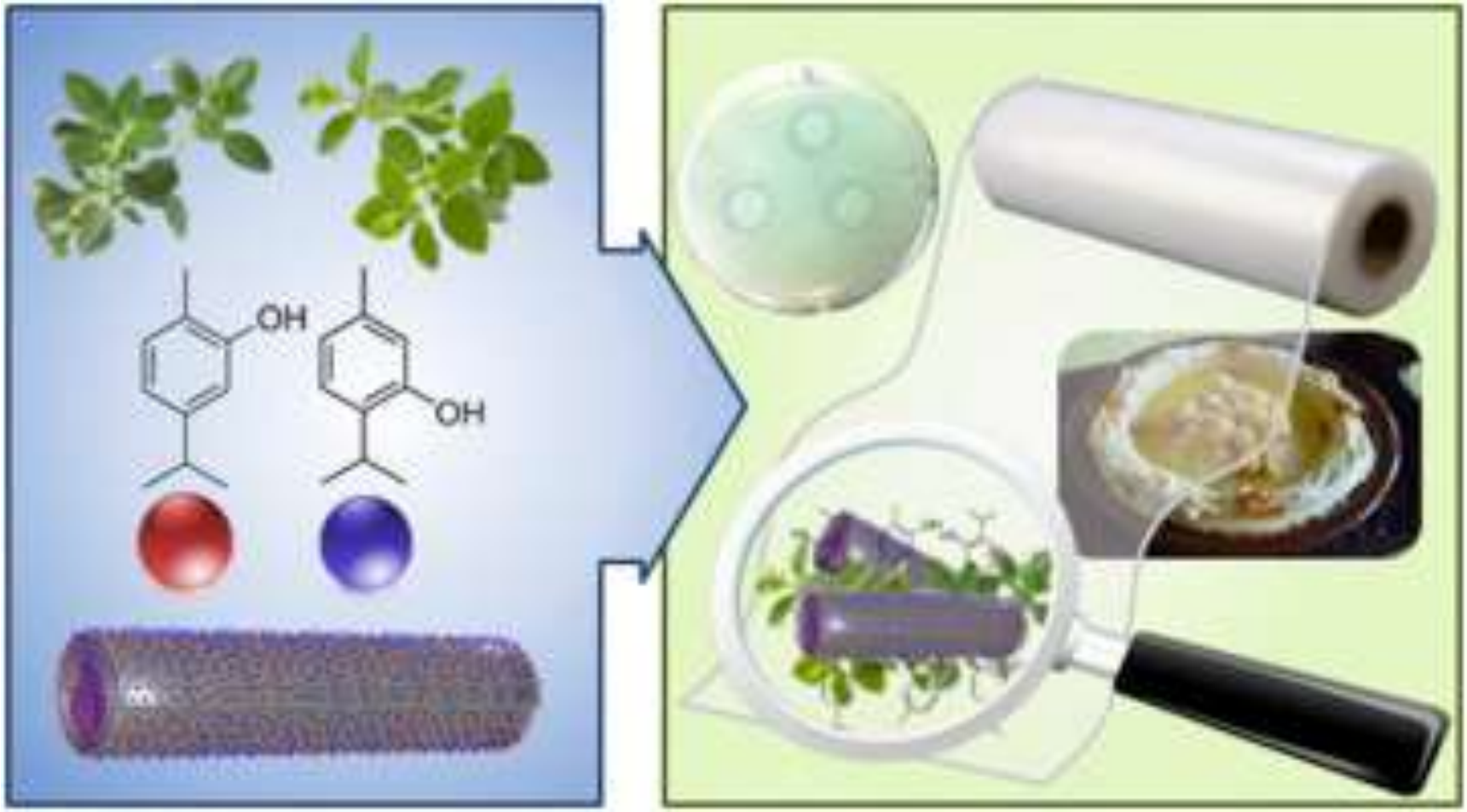


P2B SBS PLA



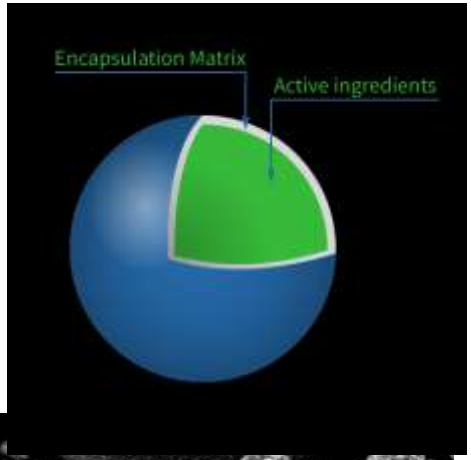


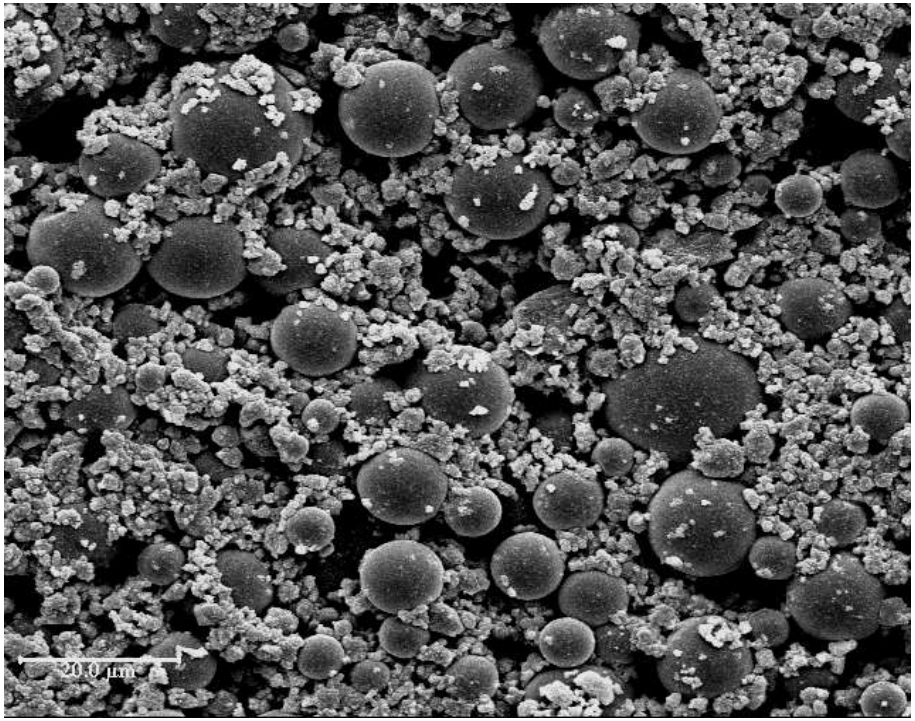
Spinning and Microencapsulation

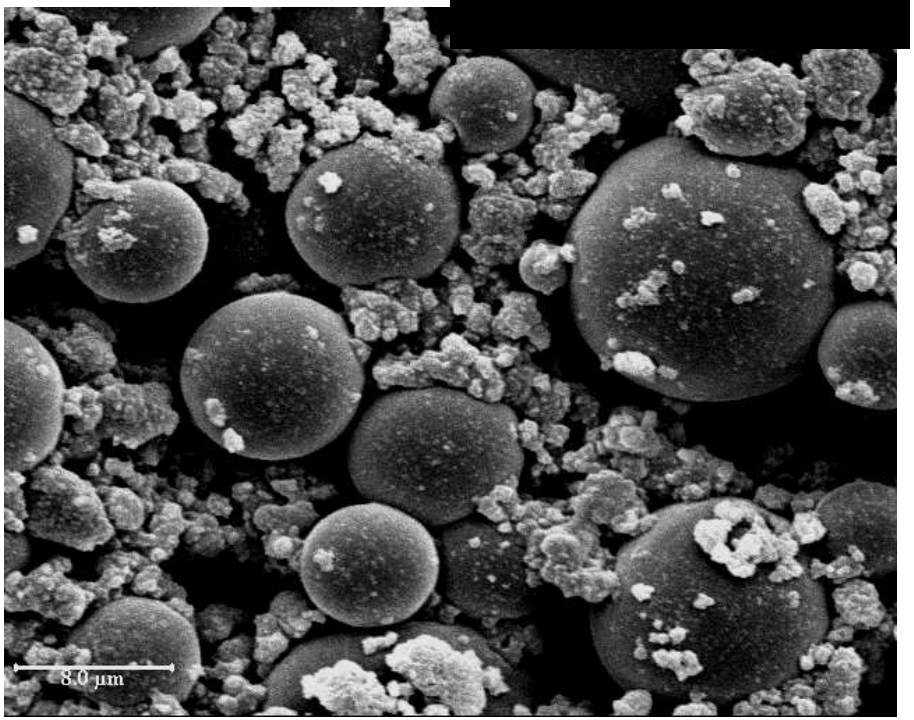


Microencapsulation

1. Aminoplaste Encapsulation





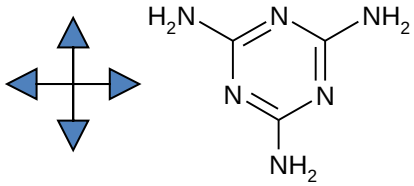


Microencapsulation

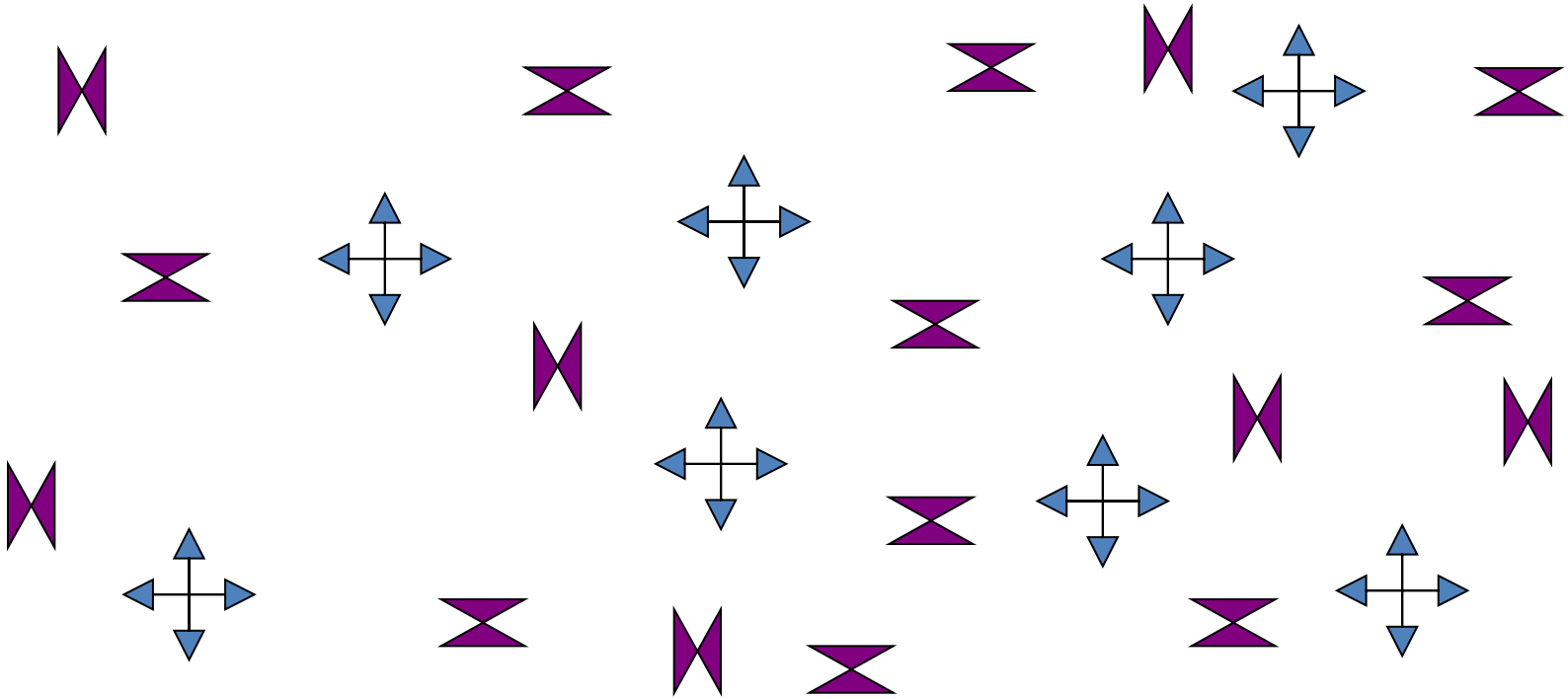
1. Aminoplaste Encapsulation

- Polycondensation non linéaire

Melamine

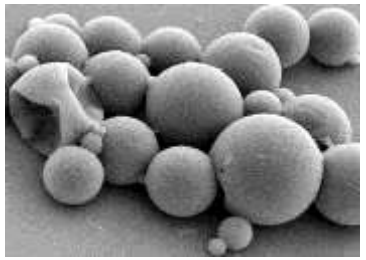


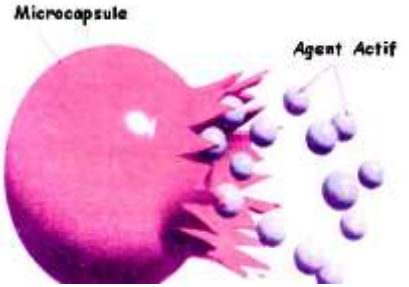
Formaldehyde



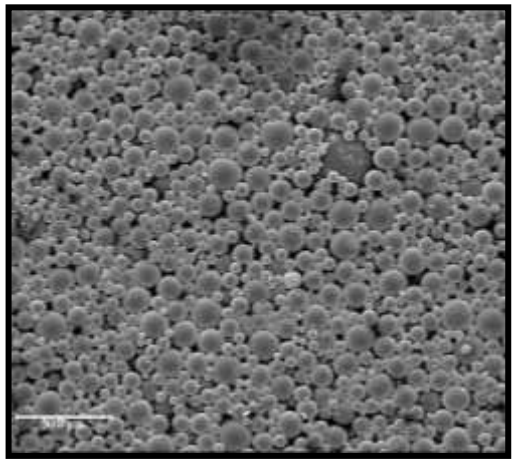
Microencapsulation

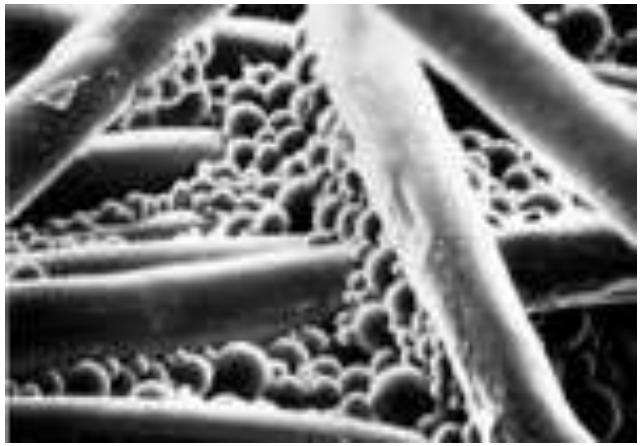
2. Coacervation

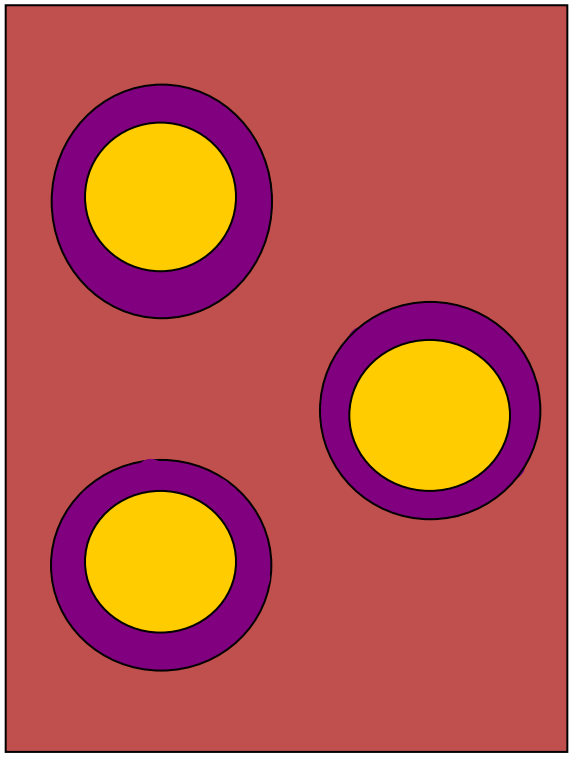




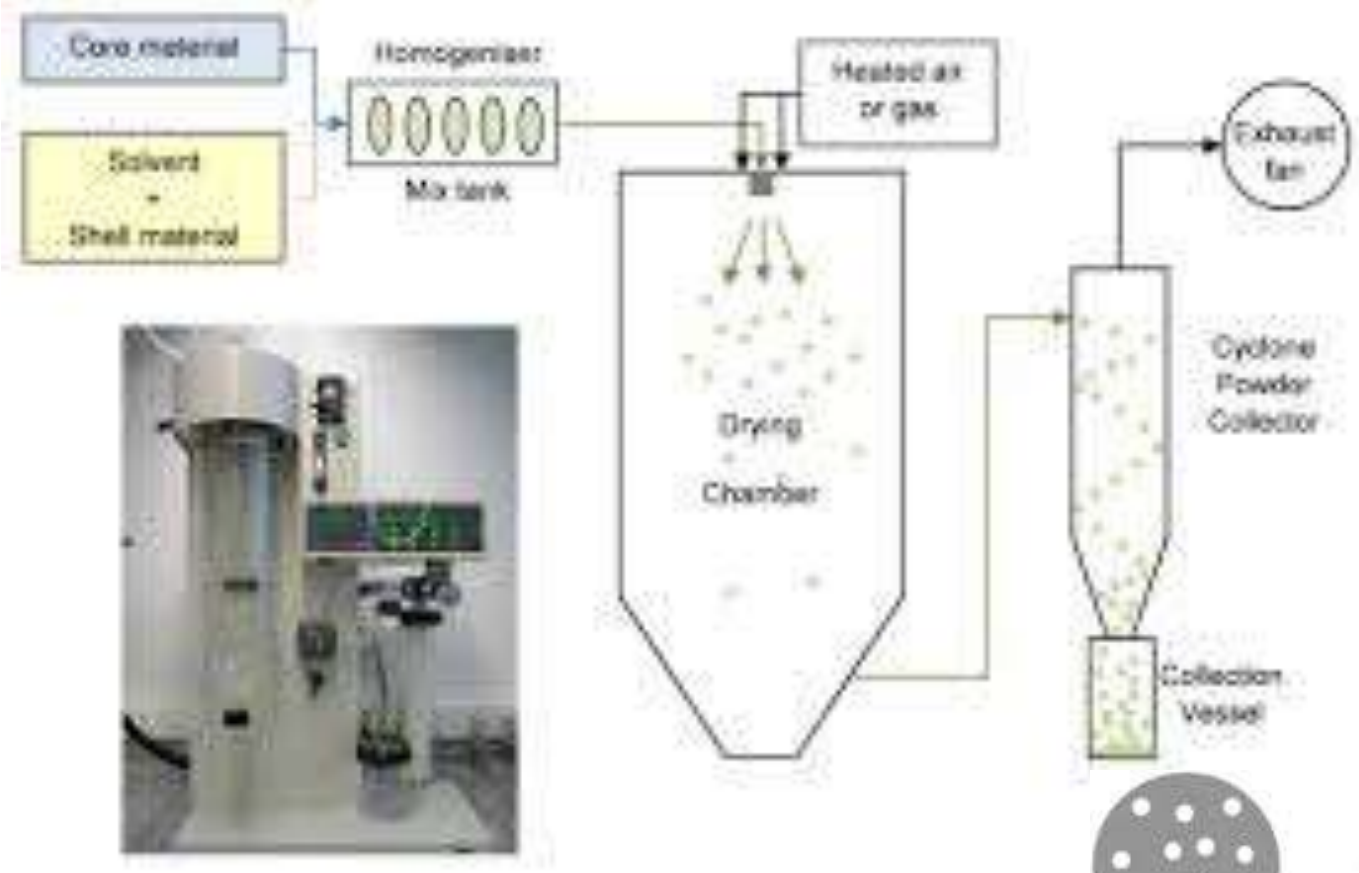
- Principe
  - Active agent in polymer emulsion
  - Physico-chemical parameter change
  - Precipitation & coacervation on micels
  - Solidification of shell

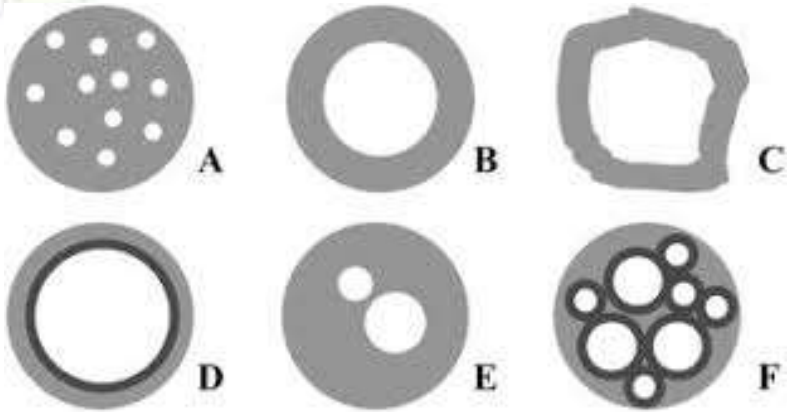




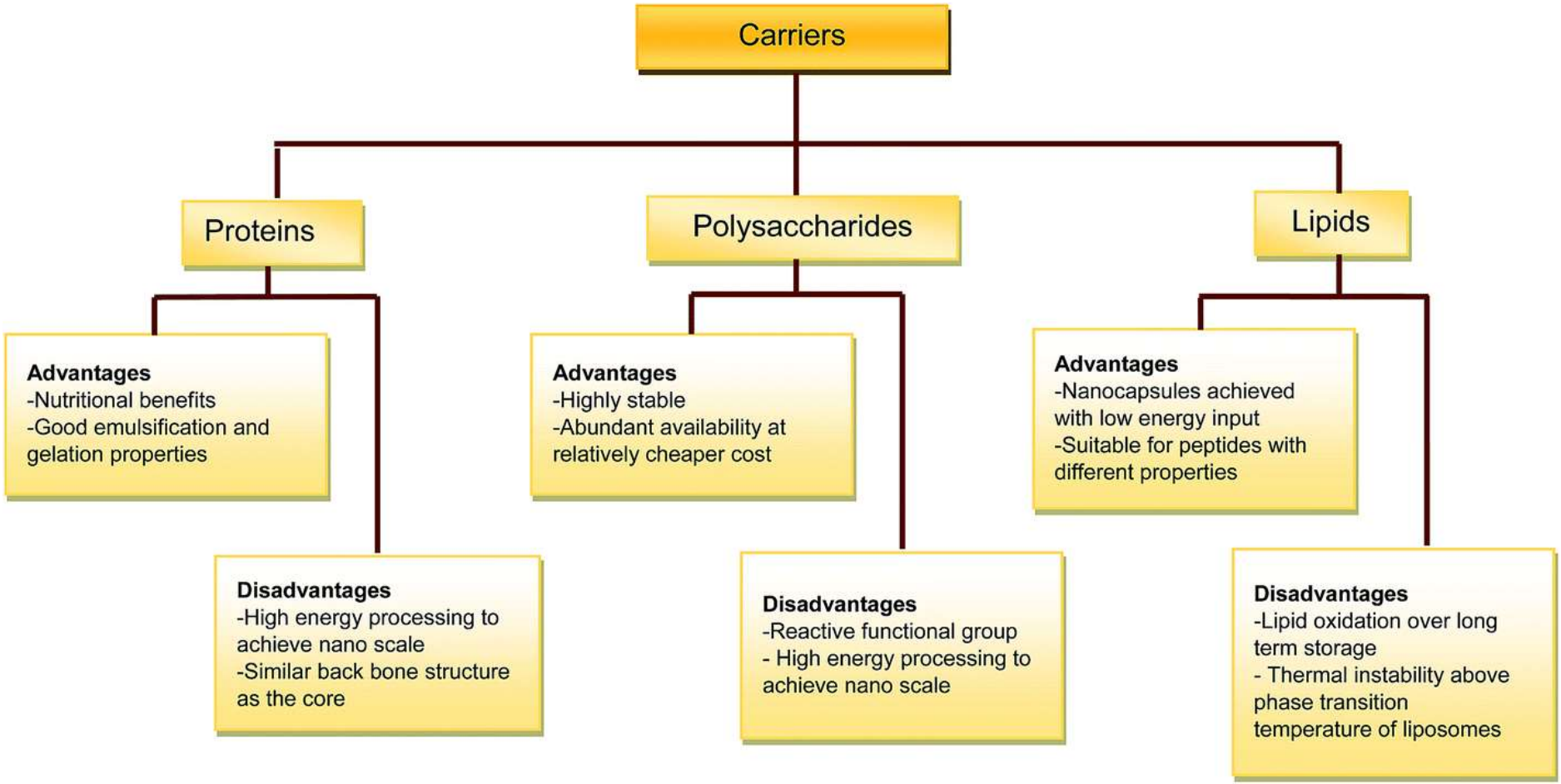


Microencapsulation





Microencapsulation



Microencapsulation

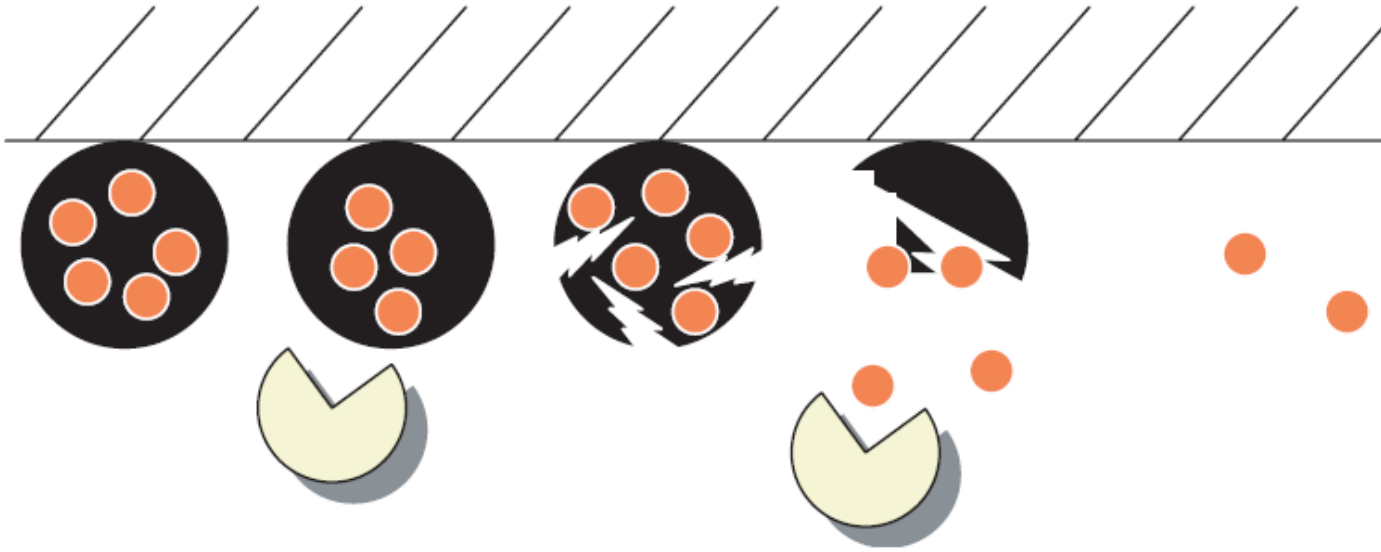


Figure 2. Schematic representation of anti-microbial active-packaging. Micro-organisms hydrolyze starch-based particles, causing release of the antimicrobial lysozyme, resulting in inhibition of microbial growth.

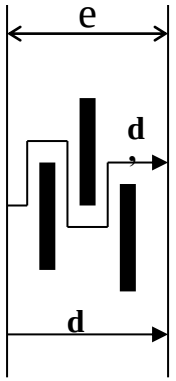
OUTLINE

- NEW SOLUTIONS IN MATERIALS
  - Antimicrobial Peptides for Bioactive Packaging
  - Cellulose nanofibers (CNF) as a new opportunity
- NEW SOLUTIONS IN PROCESSES
  - Encapsulation systems in the packaging material
  - Electrospinning for active materials
- NEW CONCEPTS IN ACTIVE PACKAGING
  - Bionanocomposites for active packaging

Nanocomposites

↳ **decrease permeability to gases:**

1. … nanoloads with high ratio Length / thickness
⇒ increase of the tortuosity



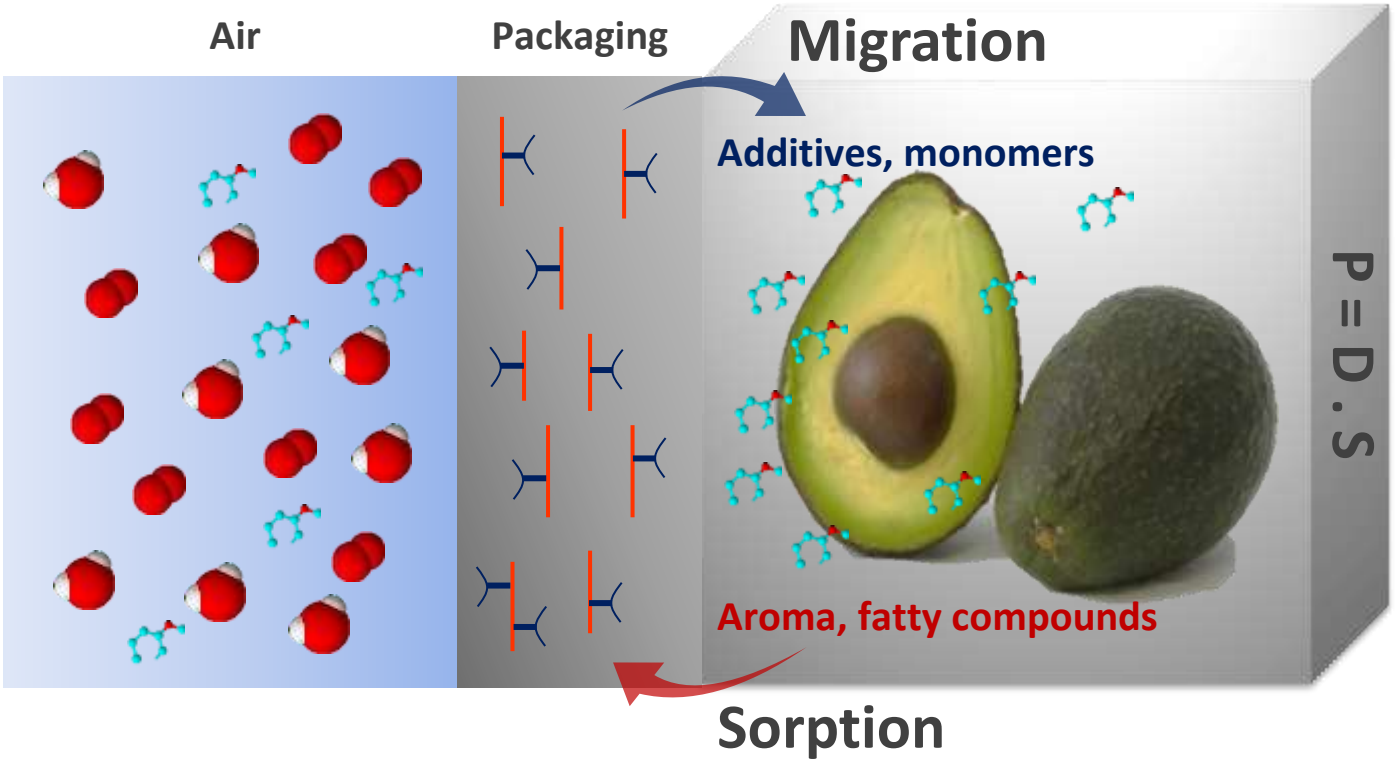
2. … a perfect dispersion of the nanoloads allowing their orientation (case of exfoliated nanocomposite)

Example: O_2 and CO_2 transmission rates halved compared with standard films

PA 6 or PET + nanoclay :

- ↳ O_2 barrier : + 50 to 80%
- ↳ CO_2 barrier : + 60 to 80%

Nano scavengers



Develop materials with functional barriers by the inclusion of biobased nanoadsorbents (CNC) in a polymer matrix

Espino-Perez, E; Bras, J; Almeida, G; Relkin, P; Belgacem, N;; Plessis, C. Domenek, S. , Cellulose nanocrystal surface functionalization for the controlled sorption of water and organic vapours, Cellulose, (2016),

Nano scavengers

Engineering training

Eloi Mortain

Lab process

Challenges!

- Find a CNC feeding method for ensuring good dispersion in PLA
- Optimize the extruder profile to avoid CNC degradation
- Develop one-step CNC functionalization by ***SolReact*** & incorporation in PLA

Up-scale

Doctoral summer training

Etzael Espino

Nano scavengers

GASP (ANR)

High Barrier biobased polymer forpackaging

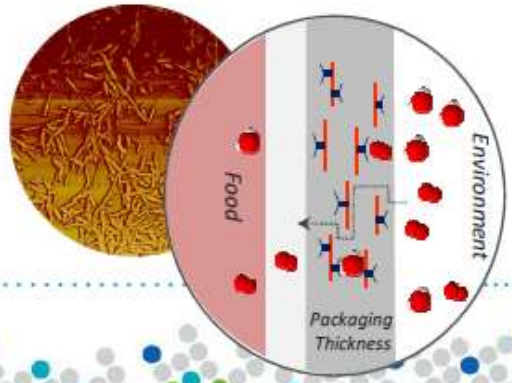
Optmise nanofiller-Bioplastic interface and interphase to develop 100% biobased high barrier to gaz packaging

PI:

Partners:

GENIAL (INRA) (91)

CGL Pack (74)
ICMMO – Université Paris Sud (91)
IMP – Université Lyon 1 (69)
LGP2 - INP Grenoble (38)
PBS - Université de Rouen (76)
PIMM – CNAM (75)
Wipak (59)

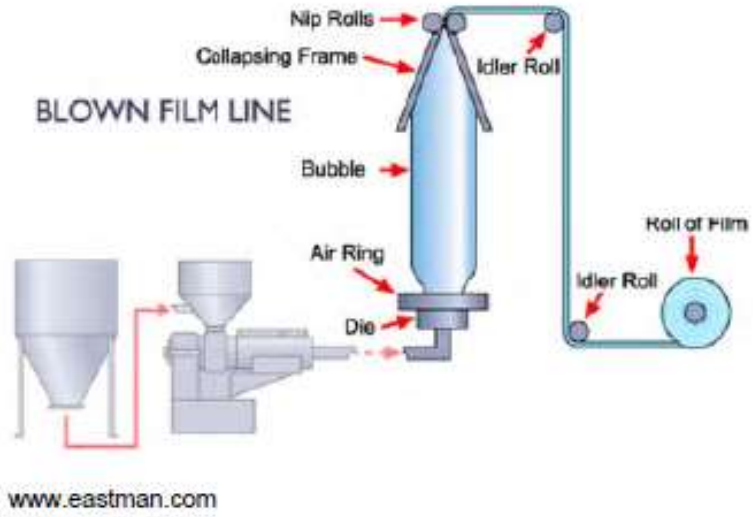


Budget: 2 635 082 €

Time: (2016-2020)

Nano scavengers

Blown-Film Extrusion of PLA and PLA/CNC Composites



PLA, BUR = 5

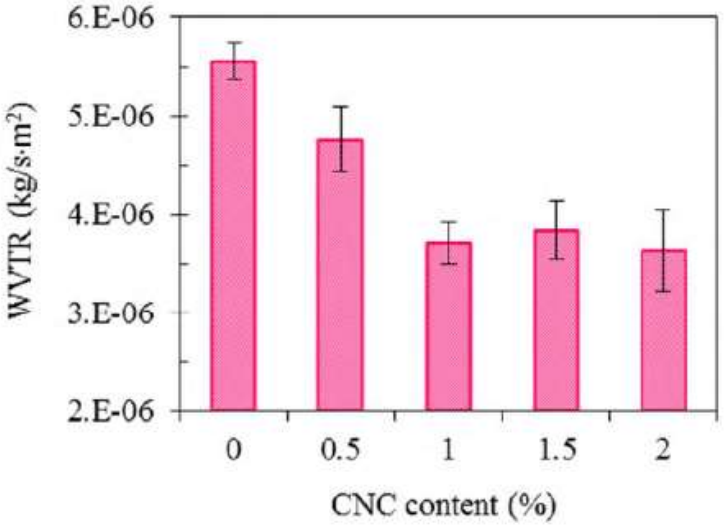
2% CNC/PLA, BUR =5

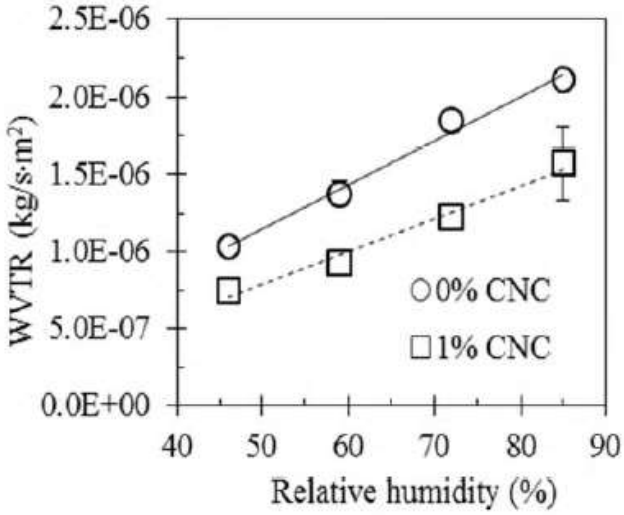
(Karkhanis et al., Journal of Applied Polymer Science, 2017)

N.Stark, Tappi 2017

Nano scavengers

Water Vapor Barrier Performance





38 °C, 85% RH

Gas Permeability

Samples	Permeability (10^{-18} kg-m/m²-s-Pa) at 23°C	
	Oxygen 0% RH	Carbon dioxide at 0% RH
Control	9.69 ± 1.97	27.6 ± 0.28
1% CNC	3.71 ± 0.32	17.9 ± 0.01

N.Stark, Tappi 2017

Nano scavengers

Discoloration of Cut Lettuce

PLA

PLA/0.5% CNC

7 days 14 days

N.Stark, Tappi 2017

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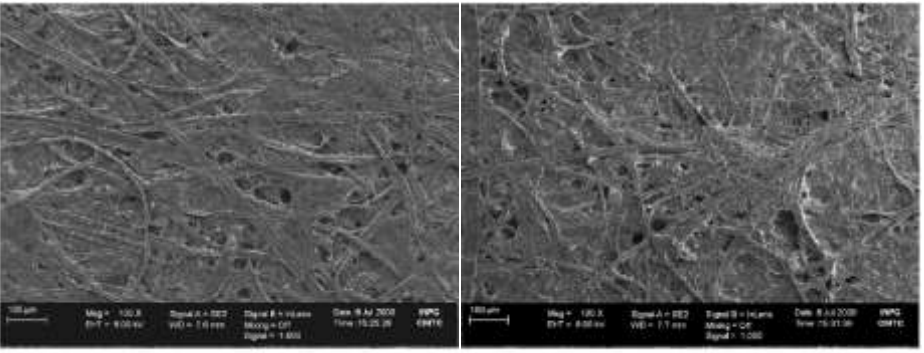
- NEW CONCEPTS IN ACTIVE PACKAGING
  - Bionanocomposites for active packaging

Conclusions

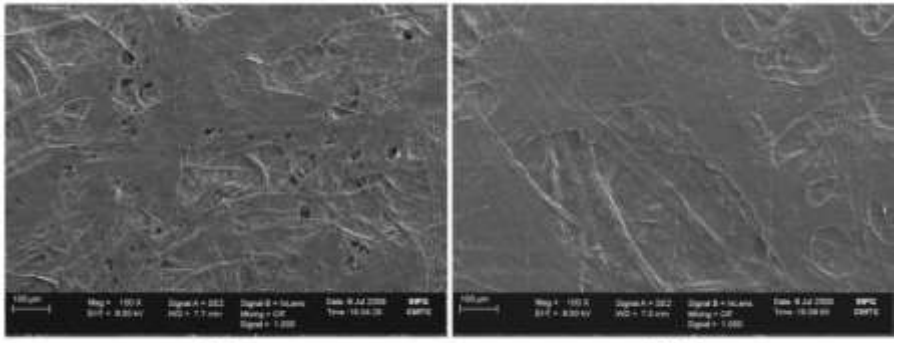
Conclusions

- New active packaging but not so many new technologies
- High focus on new nanomaterials or new peptides
- Nanocellulose promising biomaterials
- What about scavengers ?
- What could be next process / technology ?

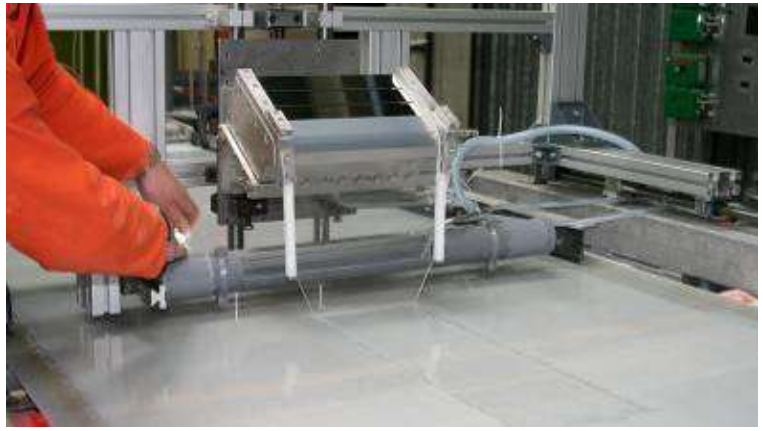
Next: New technologies?



pulp A4



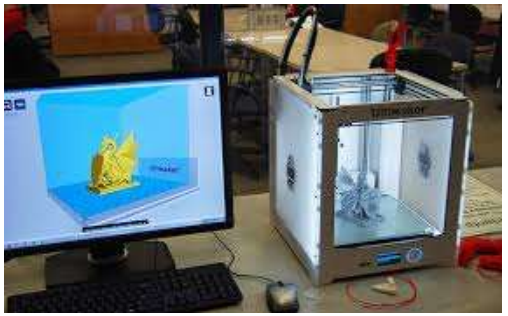
MFC1 MFC2

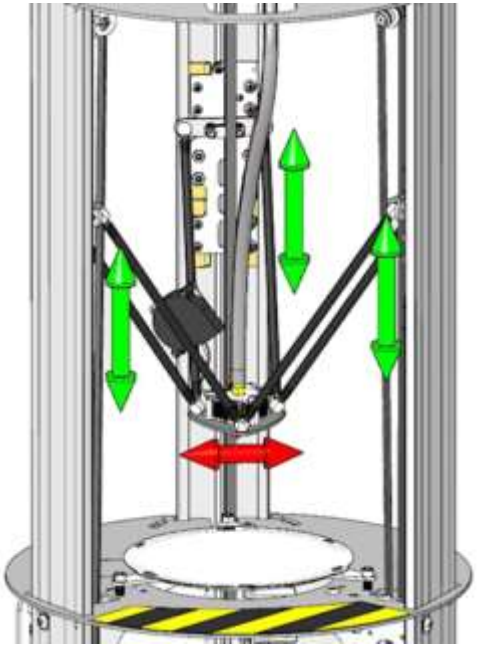


CTP's curtain coater located above Grenoble INP Pagora's paper machine

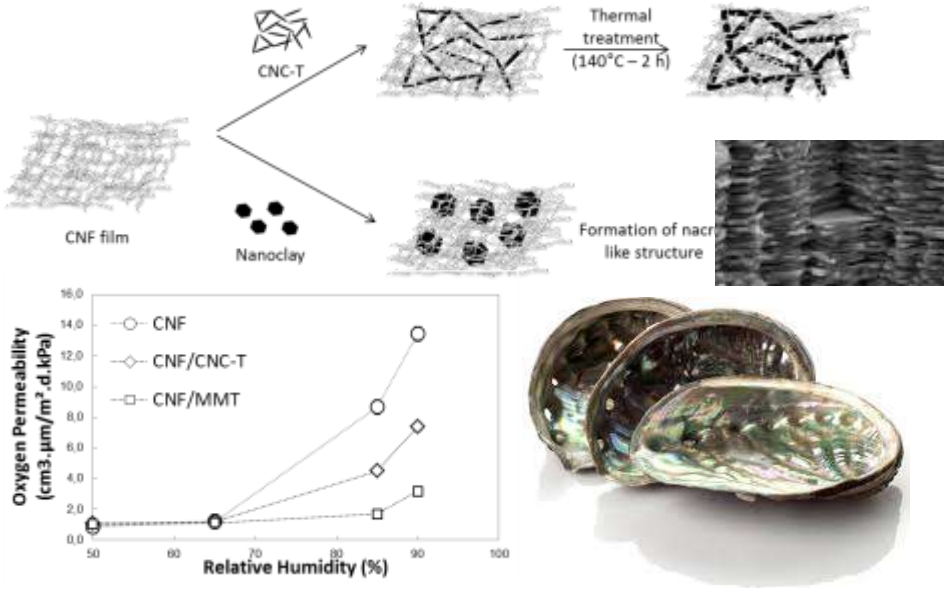
Next: Additive technologies?

3D Printing ?

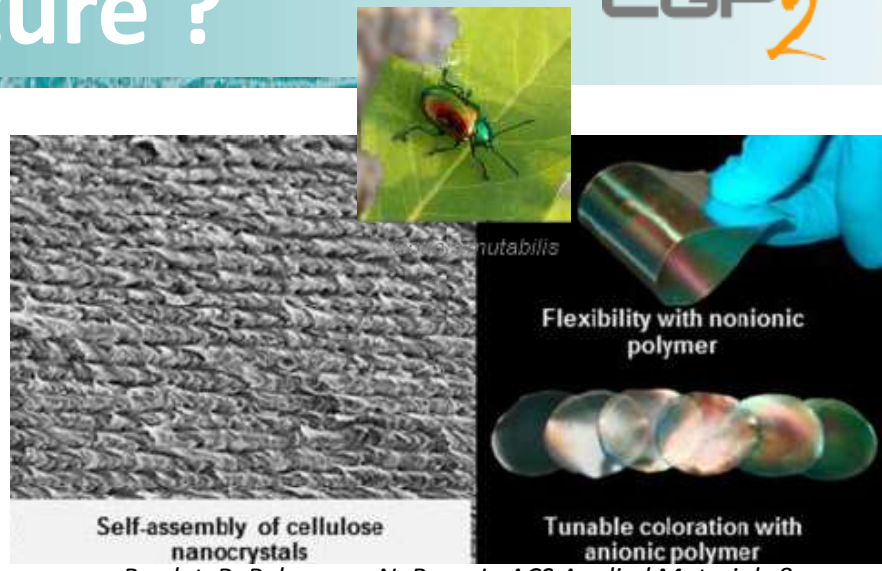




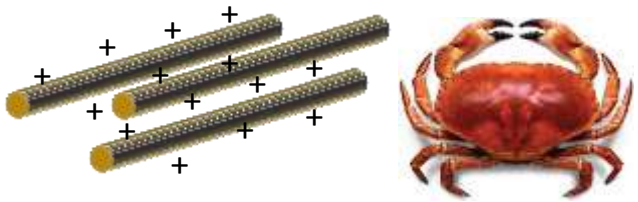
Next: Inspired from nature ?



Bardet, Reverdy, Belgacem, Leirset, Syverud, Kristin, Bras, J (2015) Cellulose, 22(2), 1227-1241



Bardet, R; Belgacem, N; Bras, J,, ACS Applied Materials & Interfaces (2015), 7(7), 4010-4018.



S. Saini, C. Yucel-Falco, M. N. Belgacem, J. Bras Carbohydrate polymers (2015), 135, pp 239-247.

Be inspired by Nature

THANK YOU FOR YOUR ATTENTION

Julien.Bras@grenoble-inp.fr

Join us in the LinkedIn group « Nanocellulose Materials »

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tec21 the engineering of complexity

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