Laboratoire de Génie des Procédés pour la Bioraffinerie, les Matériaux Bio-sourcés et l'Impression Fonctionnelle

Laboratory of Process Engineering for Biorefinery, Bio-based Materials and Functional Printing

UMR 5518

YEAR BOOK 2025

lgp²

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UGA Université Grenoble Alpes
GRENOBLE INP UGA
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lgp2.grenoble-inp.fr

All editions of the Yearbook

INSTITUT CARNOT PolyNat

tec21 the engineering of complexity

Few words from the head of the lab

Anne BLAYO,
Head of the LGP2 lab

We are particularly pleased to present the 2025 edition of the LGP2 *Yearbook*. This is an important year, as it marks the laboratory's 30th anniversary. The *Yearbook* is made up of mini-posters prepared by the laboratory's doctoral and post-doctoral students, summarizing their research topics and the progress of their work.

Rather than an annual activity report in the conventional sense, the 2025 *Yearbook* is therefore a snapshot of all the topics currently being studied within the laboratory.

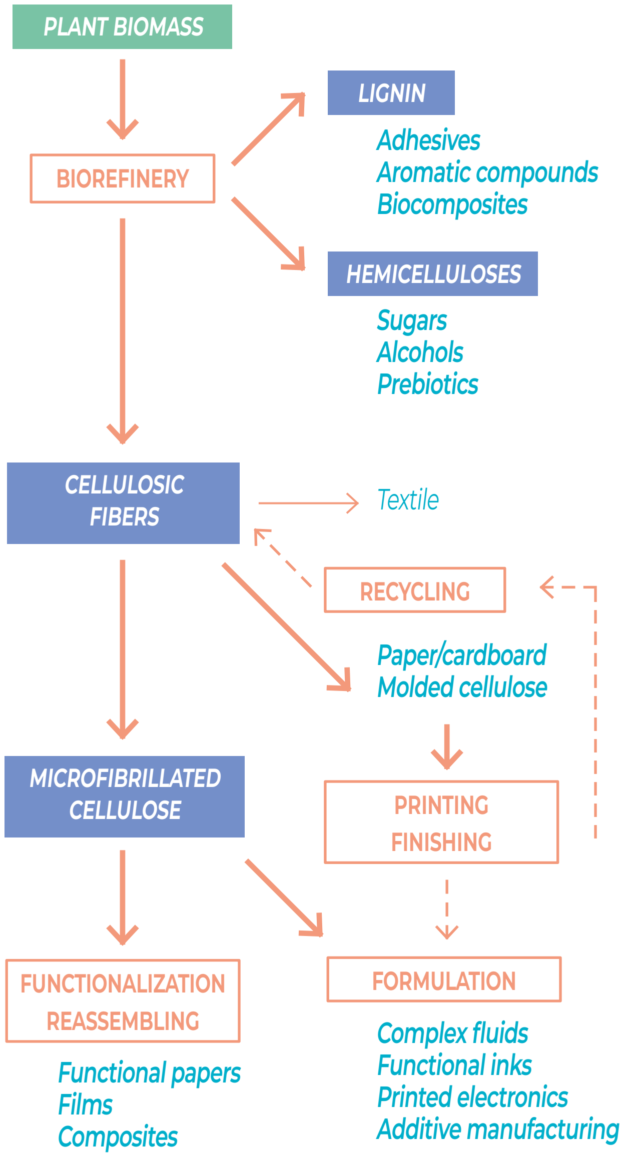
The 2025 Yearbook features summaries of some thirty current research projects, organized in chronological order. In line with previous editions, it demonstrates the strong anchoring of LGP2's themes in the field of biobased materials, lignocellulosic materials recovery and functional printing, with an ever-increasing emphasis on sustainable development, recycling and eco-design.

The *Yearbook* also gives an insight into the diversity of collaborations between LGP2, other research laboratories and industrial partners, as well as the variety of ways in which projects are funded.

I'd like to extend my warmest thanks to all the young researchers who have agreed to contribute to the 2025 *Yearbook*, and who have made an effort to make their work accessible in a short format. Many thanks to Dr. Aurore Denneulin, Deputy Director of LGP2 and head of the Funprint team, who collects the mini-posters from researchers every year, and to Antoine Julien, LGP2's Communications Manager.

I hope you enjoy reading this issue and discovering the research topics underway at LGP2 in 2025.

An overview of the LGP2



At the very heart of sustainable development

LGP2 has built up a reputation in France and abroad for its research in the **valorization of plant biomass**, the development of **biobased materials** (paper, cardboard, composites), recycling processes, **nanocelluloses**, **printing processes for surface functionalization** and printed electronics.

In line with the **principles of eco-design** and **the challenges of sustainable development**, these research projects help to reduce the impact of human activities on the environment.

High-quality collaborative research

European projects, **ANR**, Idex and numerous direct industrial partnerships.

Member of the **LabEx Tec21**, **Institut Carnot PolyNat** and **Bioeconomy for Change** networks.

Strong synergies with the **Grenoble INP - Pagora, Graduate School of Engineering**.

Quality, Safety and Environment certified (ISO 9001, ISO 14 001, BS-OHSAS 18 001).

60 PUBLICATIONS EACH YEAR | **2 / 3 PATENTS EACH YEAR** | **2 RESEARCHERS ARE MEMBERS OF THE INSTITUT UNIVERSITAIRE DE FRANCE** | **60 RESEARCHERS AND PH.D STUDENTS** | **10 PH.D THESES EACH YEAR**

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Organization : 3 research groups

BioChip

Biorefinery: chemistry and eco-processes

Dr N. Marlin (HDR)

- Plant biomass fractionation processes
- Valorization of plant biomass fractions

MatBio

Multi-scale bio-based materials

Pr J. Bras

- Building blocks extracted from plant biomass
- Suspensions & blends: material process engineering
- Composites and fiber-based materials for packaging, healthcare and transport

FunPrint

Surface functionalization by printing processes

Dr A. Denneulin (HDR)

- Formulation and characterization of complex fluids
- Design and characterization of structured functional systems and components

Young Researchers' research projects description

Ph.D. students

Nassim AFIOUNI

Ph.D. thesis (2024-2027)
LGP2 (B. Michel; G. Mortha; C. Quesada Salas)

Processes for the Oxidation of Lignin kraft for the Integration of Antibacterial Nanoparticles in the Papermaking Process

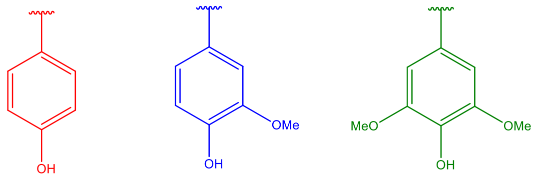
Procédés d'oxydation de la lignine Kraft pour l'intégration de nanoparticules antibactériennes dans un process papetier

BioChip

Context

What is Lignin?

- **Origin:** One of the three main components of wood
- Currently mainly valorized for energy production by combustion
- **Structure:** Highly heterogeneous polymer, constituted of monolignols with phenolic nature:



H unit | G unit | S unit

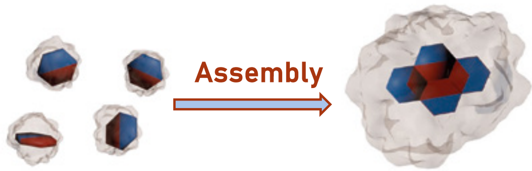
Lignin Nanoparticles (LNPs)

- Benefits: increased surface area, homogeneity and reactivity.

Funded by: GRENOBLE INP UGA; UGA Collège Doctoral ED I-MEP²

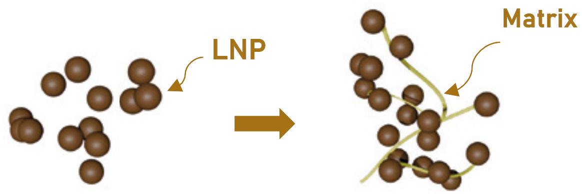
Objectives

- **Transform** raw kraft lignin into uniform nanoparticles (LNPs)
- **Synthesize** LNPs with controlled size, morphology, and surface properties.



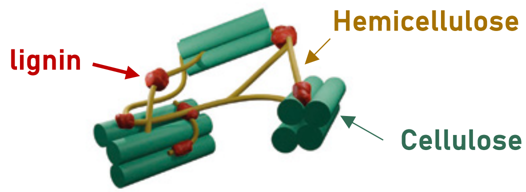
❑ Soluble functions ❑ Non-soluble functions

- **Investigate and modify** to bring specific antibacterial properties by chemical modifications
- **Integration** of LNPs on a ligno-cellulosic matrix



Methods

Lignin extraction from Kraft black liquor



- *Characterisation:*
  - Phenolic, carboxylic, methoxy content
  - Molecular weight and sugar content
  - Antibacterial properties

Lignin nanoparticle formulation by self assembly using an antisolvent with and without chemical modification

- *Characterisation:*
  - Shape, size and morphology via DLS, AFM and TEM
  - Antibacterial properties

Elsa BIHEL
Ph.D. thesis (2024-2027)
LGP2 (A. Denneulin; A. Blayo)
ICCF (D. Boyer)

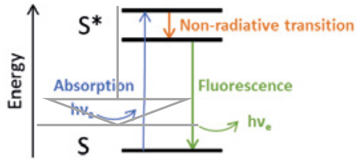
LUMNI – Luminescent nanoparticles design for the development of high-performance luminescent functional inks

Synthèse de nanoparticules luminescentes pour le développement d'encres fonctionnelles luminescentes hautes performances

FunPrint

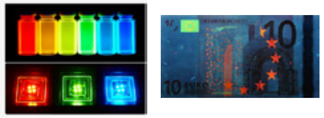
Context

Fluorescence: unique property of emission of a lower energy photon after absorption



Usually:
$h\nu_a \neq h\nu_e$
UV → Visible

Growing demands for numerous applications:
- Anti-counterfeiting
- LED display
- LDS in PV



Need for simplified deposit: additive processes

Need for more sustainability: non-toxic components and processes

Funded by: GRENOBLE INP UGA; UGA COLLÈGE DOCTORAL ED I-MEP²

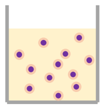
In collaboration with **ICCF**: ICCF Institut de Chimie de Clermont-Ferrand

Objectives

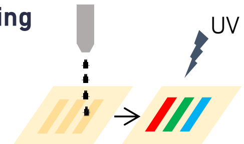
Development of a high performance RGB sustainable luminescent ink

1. **Selection of luminescent particles**
   Efficient selection - Favor dispersion in targeted media

2. **Formulation of an ink**
   Control of the dispersion in different media (aqueous)



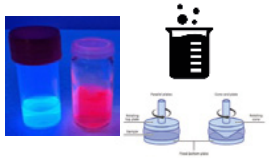
3. **Ink deposition / processing**
   Inkjet – Screen printing
   Interaction ink – process – substrate



4. **Color management - applications:**
   Red / Green / Blue Fluid design

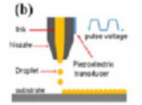
+ Sustainability

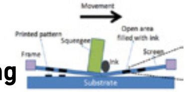
Methods

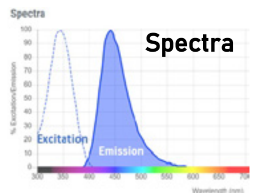


Fluid formulation:
Formulation and mixing
Rheology and physico chemistry properties

Processability:
Deposition processes
Surface and interface

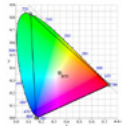


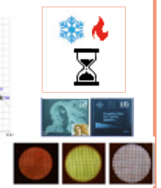


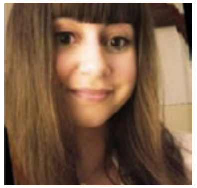


Optical characterization:
Excitation-Emission spectra/ Quantum Yield / Stability

Post-printing properties:
Time stability
Color management
Applications







Lilou BOUTARIN
PhD. thesis (2025-2028)
LGP2 (A. Denneulin; J.Bras)
LMGP (D.Bellet)

Eco-design of optically active multi-layered systems by full printed approach: materials-process correlations

Eco-conception de systèmes multicouches optiquement actifs par approche totalement imprimée : corrélations matériaux-procédés

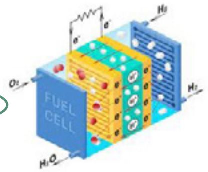
FunPrint MatBio

Context

Electrochromic devices

Smart windows
Planes, cars, buildings

Flexible displays
Solar cells, captors



Other technologies
Fuel cells, printed battery

Printing technologies advantages

- Low production's cost
- Eco-friendly components
- Large deposition surfaces
- Flexible surfaces

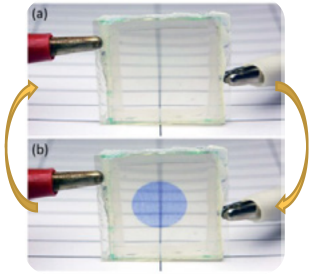
Funded by / in collaboration with:

icmcb, lgp², anRT (Association Nationale Recherche Technologie)

Objectives

Create a device which can change their color when a electrical voltage is applied (reversible action)

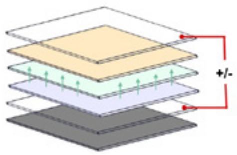
Voltage < 0V



Voltage > 0V

- Good optical properties
- Durability after several cycles of use
- Electrical and thermal stability
- Low switching time between the two state

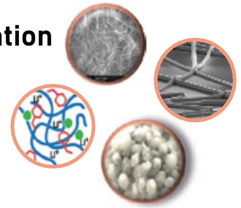
Study the interface phenomena



Methods

Nano particles characterization

- Cellulose
- Silver nanowires
- Electrolyte
- Metallic oxide particles

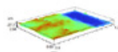


Fluid engineering

- Electrochromic ink
- Electrolyte ink
- Transparent conductive ink

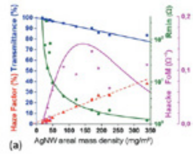
Printing processability

- Rheological properties
- Characterization of unique layers



Materials physics

- Experimental and modelling approaches
- Stability assessment under stress



Julien CLAUZON
Ph.D. thesis (2024-2027)
LGP2 (R. Passas; Q. Charlier)
3SR (S. Rolland du Roscoat)

Multiscale Characterization of the Hygro-Mechanics of the Fiber Mats

Caractérisations multi-échelle de l'hygro-mécanique des matelas fibreux

BioChip
MatBio

Context

Packaging industry

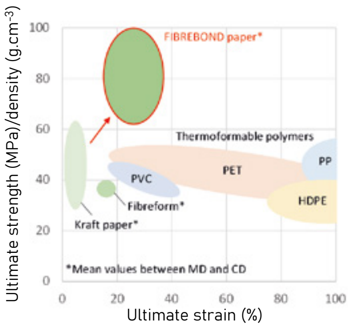
140 MT of non-degradable petroleum based polymers worldwide in 2021.

Paper

It is an **alternative** but is strongly limited by its **weak ductility**.

To face the growing demand while limiting its environmental impact**, the paper industry must reduce its consumption of energy, water and raw materials.**

Paper should be:
- **stronger**,
- **extensible,**
- **lower basis weight**



Funded by: anr FiberBond ANR 2024-2028

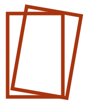
Objectives

Goal of this project

Get a better understanding of the inter-fiber bonds behavior and its impact on paper hygro-mechanical properties using a multiscale approach. This is done using different fiber morphology and fiber mat density.

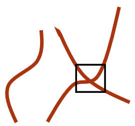
Study paper at different scale

- **Macro scale**: paper sheet



- **Meso scale**: fiber network

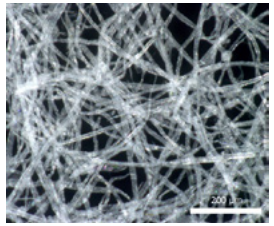
- **Micro scale**: fibers and fiber bonds



Methods

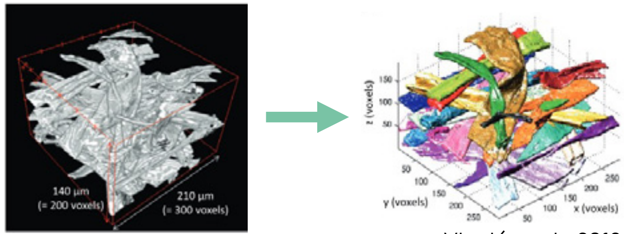
Model sample

6 g.m^{-2} handsheets samples made from various pulp using a Rapid Köthen and 1 µm mesh wire



X-ray microtomography and segmentation

Allows for the 3D reconstruction and labeling of samples to study 3 scales at the same time: Fiber network, individual fibers and the fiber contacts.



Viguié et al., 2013

In-situ hygro-mechanical testing

Mechanical testing done using a micro-press under a climatic chamber while being scanned by X-ray microtomography. Allows for a morphological and mechanical characterization at different humidity.

Valentin GEMIN

Ph.D. thesis (2024-2027)
LGP2 (N. Belgacem; C. Sillard; J. Viguié)

NAPKINS, Structure-properties relationships of wet and dry fiber foam for absorbent and retentive sanitary pads

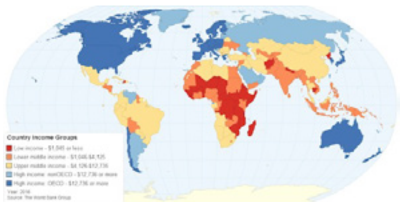
NAPKINS, étude propriétés-structures des mousses fibreuses liquides et solides pour la fabrication de mousses absorbantes et rétentives

MatBio

Context

Develop **100% bio-based & biodegradable napkins** to replace petro-based veils & non-biodegradable super absorbent particles (SAP) that slowly break down in landfills[1]

Affordable and produced locally from **local biomass** in different part of the world to help overcome limited access, detrimental health and social consequences for menstruated people in the Global South[2]

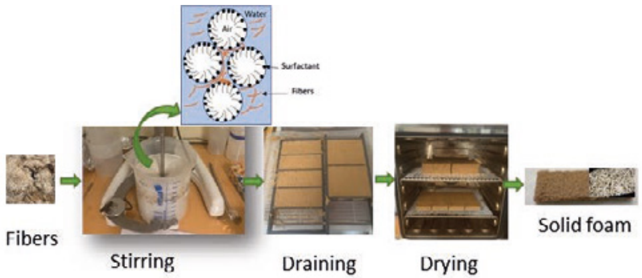


[1] C. Lacoste et al. (2019), doi: 10.1016/j.eurpolymj.2019.03.013.
[2] M. Panjwani et al., (2024) doi: 10.1007/s13399-023-04688-7.

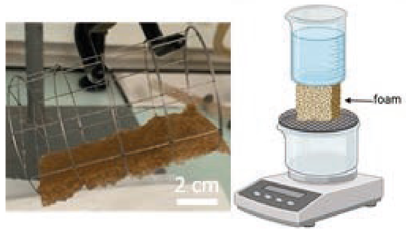
Objectives

Study the influence of surfactant and fibers physico-chemistry on retention

- Surfactants: Glucopon 600CS/UP215, Texapon V95G, SDS
- Annual plant fibers: Cotton (reference), Bamboo, Banana stem, Flax, Date palm



Water retention after 5 kPa load ~ commercial > 16 g/g with water



Methods

Surfactant and fibers supensions

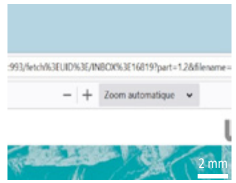
- Fibers morphology (Morphi)
- Mechanical properties of fibers
- Dynamic and static surface tension (Pendant drop/bubble tensiometry)
- Surface dilatational modulus (Oscillating pendant drop)
- Viscoelasticity (rotational rheometer)

Liquid foam

- Bubble size distribution
- Air fraction
- Half life
- Viscoelasticity

Solid foam

- Porosity, pore size
- Mechanical properties
- Absorbance
- Retention



Sarp KÖLGESİZ

Ph.D. thesis (2025-2028)
LGP2 (N.Belgacem;D.Beneventi)
PoliTO (R.Bongiovanni)

Design of an innovative wood-based biocomposite and development of its processing by 3D LDM printing and thermopressing

Elaboration d'un biocomposite innovant à base de bois et développement de sa mise en forme par procédés d'impression 3D et thermopressage

MatBio FunPrint

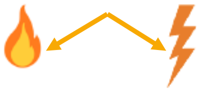
Context

Biomass processing industries

Industrial lignins

The global lignin market~**over €3 billion**

90% of extracted lignin use as a **biofuel**



So what might be other **alternative application areas** for industrial lignin?

1) Developing fully bio-based resins as a competitive and sustainable alternative to conventional petroleum-based adhesives.

Funded by: MSCA Unite!Energy

Objectives

There are different approaches alternative to current petroleum-based materials, creating different application areas for utilization of industrial lignins.

➡ To create **fully bio-based resins** which will be **formulated with phenolic groups** obtained from **depolymerized lignin** and **a bio-based alternative to formaldehyde**

↓ **Thermoplastic copolymers**

↓ **Thermoset liquid resins**

Applications:

Methods

Materials: PFA, lignin, cellulose nanoparticle ➡ Preparing composite materials

Processing

3D printing (Liquid deposition modelling)

Spary Coating or Casting

Analysis & Characterization

Chemical properties:

FT-IR, NMR, DSC

Physical properties

Viscometer (viscoelastic property), UTM and 3-point bending test machine (mechanical properties)

Morphological property

SEM, VLM, X-ray tomography

Océane AVERTY
Ph.D. thesis (2023-2026)
LGP2 (C. Martin; J. Bras; Q. Charlier)

Cellulose substrate functionalization for barrier & sealing solutions in beauty packaging

Fonctionnalisation de substrat cellulosique pour des emballages barrières et scellables dans le domaine cosmétique

Thèse confidentielle

MatBio

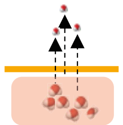
Context / Objectives

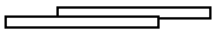
Single Use Plastic pollution

- SUPD in Europe, more and more regulations around the world
- Society expectations to have less plastic packaging

Replace flexible plastic packaging by barrier to water vapor paper packaging with bio-based coating

Reach the **barrier performance** required for high moisture products



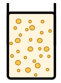


Be **sealable**

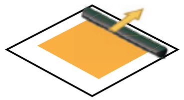
Be **recyclable and 100% biobased**

Methods

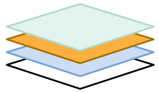
1. Suspensions formulations



2. Monitoring coating and drying parameters



A multilayer strategy to reach all the targets

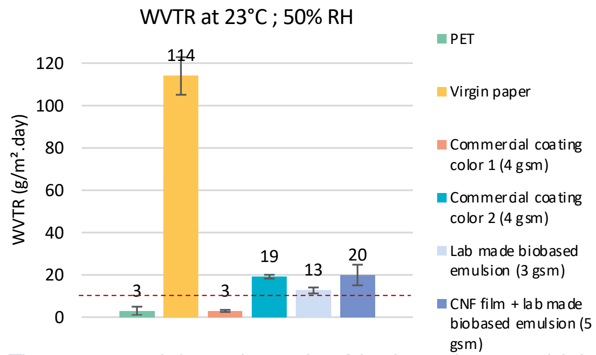


3. Characterisations of the material

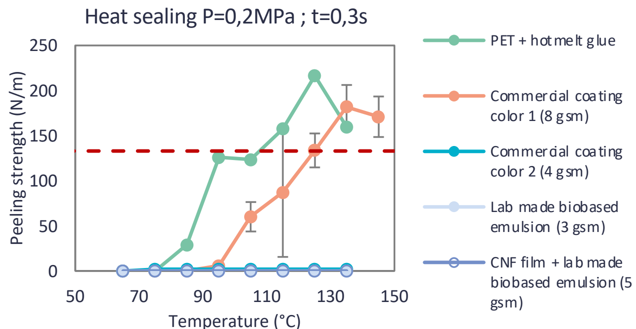
- Barrier performance
- Recyclability

- Sealability
  - Mechanical
  - Ultrasound
  - Heat

Results



The commercial coating color 1 is the only one which enables to reached the target (10 g/m².day). However, the lab made biobased emulsion is quit close to the target, which is promising.



Biobased coatings that don't behave like polymers are not heat selables.

Laura BERNARD

Ph.D. thesis (2023-2026)
LGP2 (A.Denneulin; N. Reverdy)
CEA-Leti DTIS (P. Mailley;
P. Marcoux)

Printed electronics for early detection of bloodstream infections

Electronique imprimée pour le dépistage rapide des infections sanguines

FunPrint

Context / Objectives

Bloodstream infections

- 48,9 million cases 2017
- 11 million deaths in 2017 (20% of worldwide deaths)
- Increase in antibiotic resistance, leading to the leading cause of death by 2050.

Handmade to a standardized product

Previous work have been made by manual deposit of ink. This PhD study various parameters to standardized the process of manufacture. Requirements :

- Autoclave-proof (130°C/18 min/2 bar)
- Rigid, resistant to breakage during septum perforation
- Biocompatible
- Electrically insulating
- Electrochemical sensor

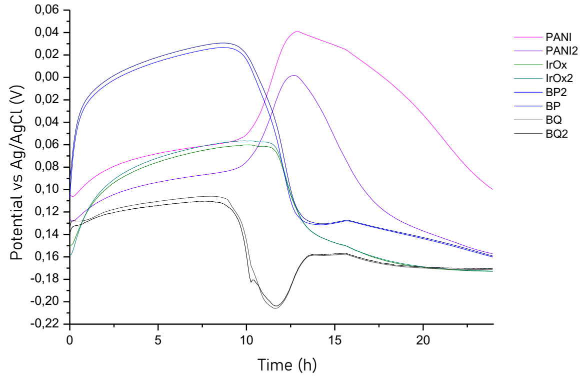
Funded by:

In collaboration with LGP2

Methods

Electrochemistry-based

pH-sensitive ink: acidification of ph detected initially then hypothesis of ink reduction by bacteria measured by a potentiostat (OCP method)



Working electrodes potential vs Ag/AgCl reference electrode during bacteria growth in Bact/Alert culture medium

Printing processes of sensor

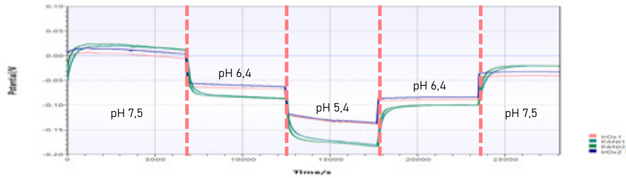
Print on PCB sensor with 2 techniques :

- Screen-printing of viscous ink
- Manual deposit of liquid inks

Results

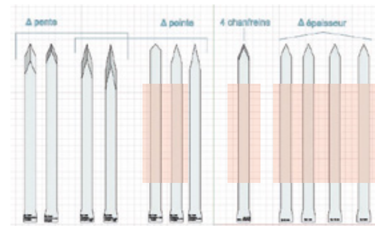
Electrochemical analysis by bacterial growth

- Results differ from those expected due to major changes compared to previous work



Electrical design and shape optimizations

Electric design evolution



3D printed prototypes to ***test de penetration*** of sensor through septum. Add, modify and test of : thickness, tip & inclination angles and chamfers

Shape optimization and perforation test

Mathilde BERNARD-CATINAT
Ph.D. thesis (2023-2024)
LGP2 (A. Blayo; E. Mauret; J. Bras) — Cellulose Valley

Development of innovative process for 3D cellulosic packaging.

Développement de procédés innovants pour l'obtention de matériaux cellulosiques tridimensionnels.

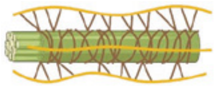
MatBio

Context / Objectives

Climate change and single use plastics: modern issues leading to various legislations push towards bio-based materials.

→ Cellulose

- Bio-based and biodegradable.
- Easily available.
- Recyclable.



→ Rigid 3D Cellulose-base packaging challenges:

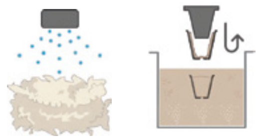
- Innovative 3D Shaping processes
- Waterless surface functionalization
- Combination of both steps

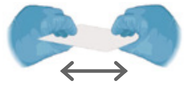
Funded by: Fondation Grenoble INP, AHLSTROM, Aptar, CHANEL, CITEO, DECATHLON, DS Smith, GUILLIN, Marie

Methods

3D shaping processes:

- Wet molded fiber.
- Dry molded fiber.
- Stretchable paper.



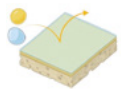


Surface functionalization:

- Spray coating.
- Pad-printing.
- Waterless coating techniques.

Combination:

- Application of barrier materials onto molded fibers.

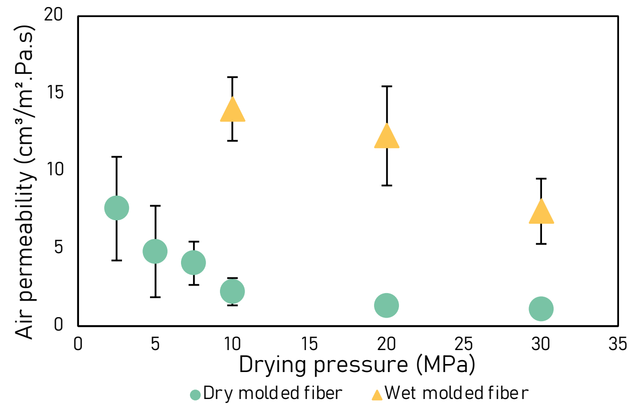


Characterization:

- Mechanical characterization (Traction, Bending).
- Surface characterization (Roughness, Epair).
- Barrier properties (Cobb, WVTR, Air permeability, Contamination monitoring after filling).

Results

High moisture material → High air permeability



Barrier solution protecting tray during oil filling

Raw molded tray

Molded tray + Barrier solution

Eliott BONNET MARTIN
Ph.D. thesis (2024-2027)
LGP2 (D. Beneventi;
A. Denneulin)
FCBA (M. Lecourt)

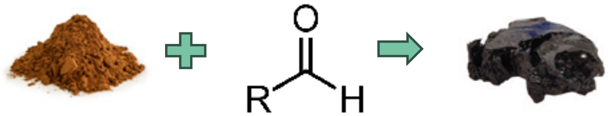
Set-up of an innovative wood-based biocomposite for processing by 3D LDM printing and wood panel adhesion

Elaboration d'un biocomposite innovant à base de bois et développement de sa mise en forme par procédés d'impression 3D LDM et thermopressage

FunPrint

Context / Objectives

Substitution for formaldehyde resin



Lignin
=> Phenol substitute (petrol based)

Bio-based aldehyde
=> Formaldehyde substitute (SVHC)

Formulated resin
100% bio-based and non toxic

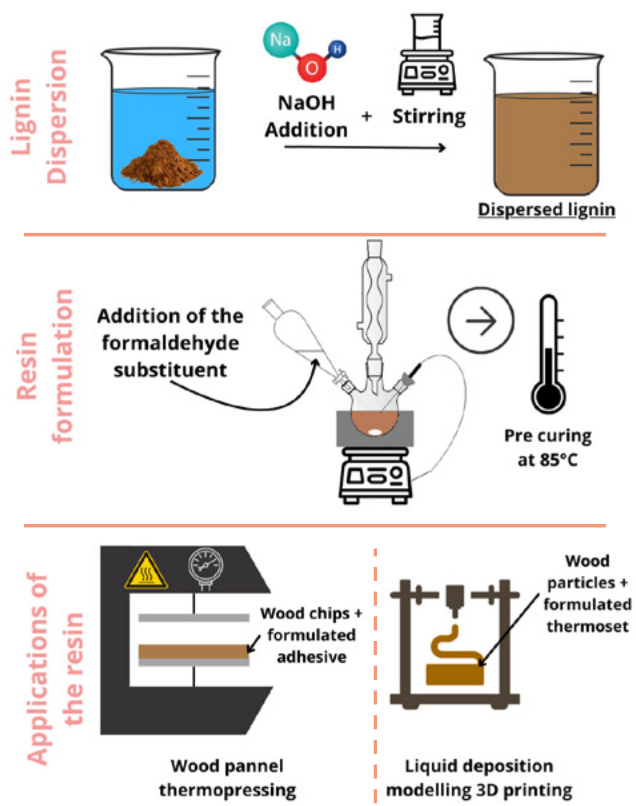
- Around 500 kT of phenol formaldehyde is produced per year for **wood panel adhesion**.
- **Bio-based** and **non toxic** substituents for phenol and formaldehyde are needed.

Lignin as a phenol substitute

- Abundant, cheap and bio-based chemical with phenolic structure.
- Potential to enhance performances of adhesive (UV resistance, thermal stability…)

Funded by: FCBA Institut technologique; ANRT Association nationale recherche technologie

Methods

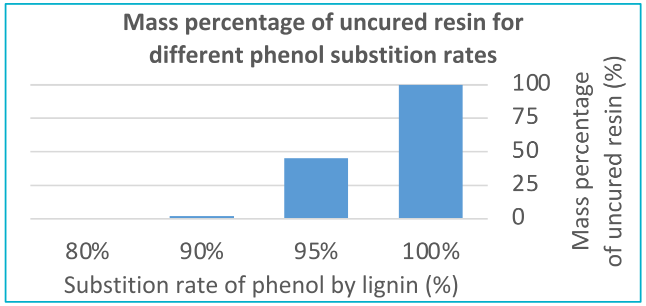


Results

Process optimization

- Dry matter content 20% ↗ to 40 % with the choice of lignin.
- Substitution of phenol by lignin 70% ↗ to 90 % with thermochemical modification of lignin before formulation.
- New chemicals identified to replace formaldehyde.

Limitations after 1 year



- Phenol substitution by lignin above 90% is a challenge.
- Bio-based phenolic coreactants are investigated.

Arnel BRZOVIC
Ph.D. thesis (2023-2026)
N. Reverdy-Bruas; N. Marlin (LGP2)
L.Svecova (LEPMI)

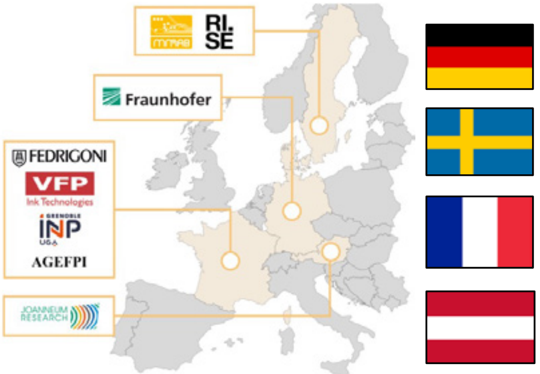
Recycling of multilayered electronic devices printed on cellulosic substrates

Etude de le recyclabilité de modèles complexes d'électronique imprimée sur papier par adaptation de lignes de recyclage papier existantes.

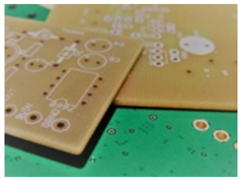
BioChip FunPrint

Context / Objectives

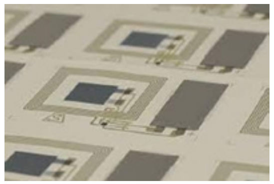
European Circel-paper project



Only **17.4 %** of the e-waste is documented to be collected and formally recycled worldwide.



FR4 PCB



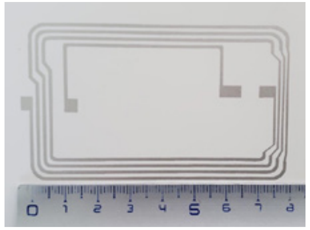
Paper PCB

- Challenges:

1) Recover the fiber fraction with minimum contaminants.
2) In a second fraction recover functional materials.

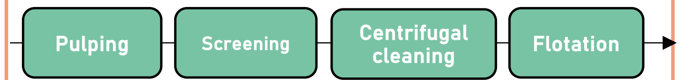
Methods

1. Paper printed electronics



Powercoat XD200
- Silver conductive Ink
- Coated paper
- 200 g/m^2

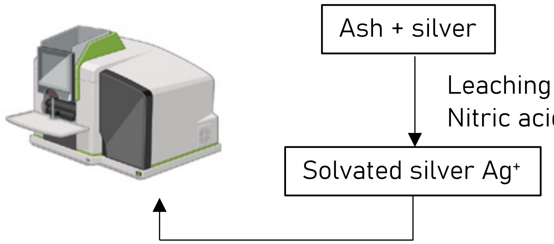
2. Conventional paper recycling line



Units are optimized individually and tested sequentially as part of the process.

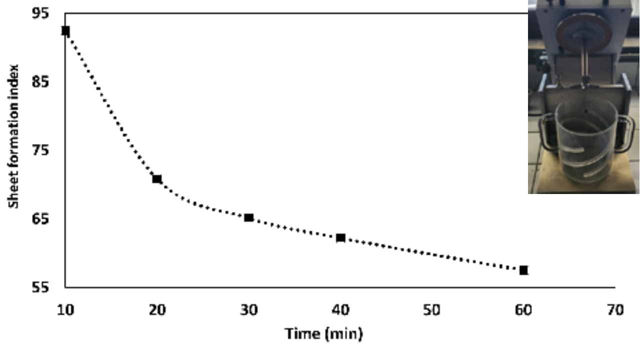
3. Atomic Absorption Spectroscopy (AAS)

Objective: silver tracking



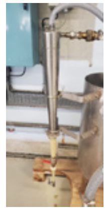
Results

1. Pulping optimization

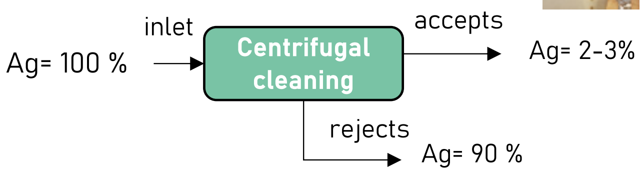


The optimization involves monitoring the properties of handsheets as they vary with several parameters.

2. Silver Recovery



Centrifugal cleaning emerges as a highly promising unit operation for the separation of silver from fibers.



→90 % of the silver can be recovered from the pulp.

Susie GUEHENNEUX

Ph.D. thesis (2024-2027)
LGP2 (G.Mortha)
IMP (F. Dalmas; F.Mechin)

Formulation of high-performance bituminous binder, mostly biobased, with a low environmental footprint

Formulation de liants « de type bitumineux » hautes performances, majoritairement biosourcés et à faible empreinte environnementale

BioChip

Context

Challenge: Reduce the use of fossil fuel (ex: **crude oil**) by 2050 *(Recommendation by IRENA)*

What? A hydrocarbon-based product derived from **crude oil** refining, known as **bituminous binder:**

- **Properties**: Waterproofing & adhesion
- **Uses** & **production**: Road industry (85%) & roofing (15%)

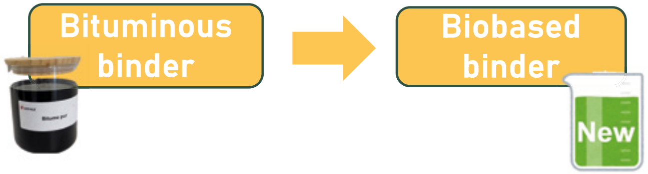
Global bitumen production/yr → **100 Mt** = **40 Mt CO_2eq/yr**

Solutions: Substitution of bitumen in binders by **bioresources** to minimize fossil-based product consumption

Funded by: EIFFAGE, SOPREMA Building for Life

Objectives

Development of a new biobased binder



With the same

- Rheological properties
- Colloidal structure

& with sustainable bioresources available on a large scale

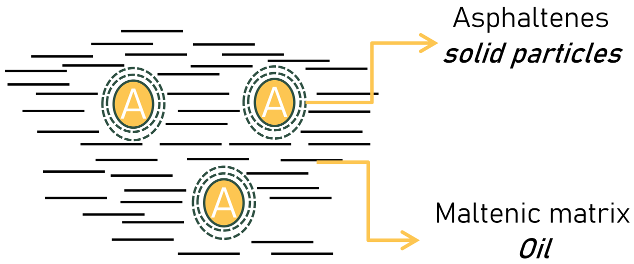


Figure : Structure of bitumen

Methods

Materials:

Aphaltenes	*Substitued by* →	**Bio polymer**
Maltenic matrix	*Substitued by* →	**Bio maltenic matrix**

Methods:

- **Selection** & **Screening** of bio polymer and bio Maltenic matrix
- **Preparation of colloidal dispersions**
  Optimization of the mixing protocol (polymer type and content, temperature and mixing time) to match the properties of commercial bitumen.
- **Dispersions characterisations**
  - Rheology
  - Microscopy
- **Understanding physico-chemical interactions**
  - NMR, SEC, SAXS

Annabelle JULIEN

Ph.D. thesis (2024-2027)
LGP2 (J. Bras; Q. Charlier)

Dry processing methods to manufacture low environmental-footprint bio-based materials

Fabrication en voie sèche de matériaux biosourcés à empreinte environnementale diminuée

MatBio

Context / Objectives

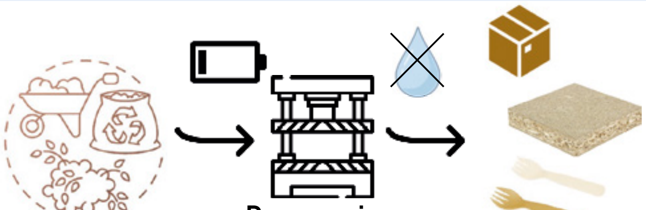
1 Environmental issues Plastic industry

- **CO2 emission**
- **Not biodegradable** so a lot of wastes finds itself in landfill or ocean (6900 Mt[1])

2 Disadvantage of current biobased solutions

- Hight **energy and water consumption**
- The use of **petroleum-based adhesives**
- **Low biodegradability** or recyclability for bioplastics

Goal : Substitute plastic by producing material form biomasses with more sustainable dry processes that uses less energy, less water, no petroleum based adhesives and that can leads to biodegradable solutions !



Understanding adhesion phenomena is key

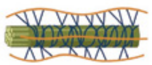
[1]Tony R. Walker et al. Trends in Analytical Chemistry 2023

Funded by:
Drybiomat - ANR-23-CE43-0002
https://anr.fr/Projet-ANR-23-CE43-0002
agence nationale de la recherche
AU SERVICE DE LA SCIENCE

Methods

Lignocellulosic material

- Wood industry by products
  → *For circular economy*
- "Pure material"
  → *To control and understand*



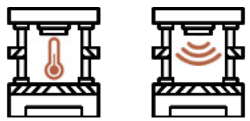
Functionalization and additives

- Biobased polymers
- Green chemistry
- Initial porous structure
  → To tune the mechanical properties

→ Different type of material shaping (powder, fiber, particle)

Dry process

- Thermocompression
- Ultrasonic compression molding



→ Different process parameters

→ Adjust **input parameters** to tailor final properties

Iterative work

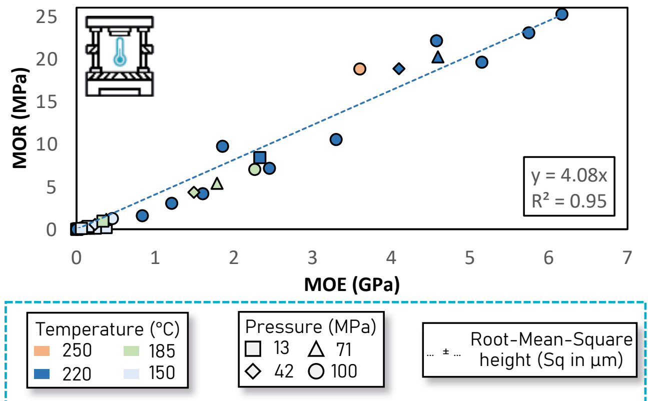
Multi-criteria analysis

Creation of a global performance index

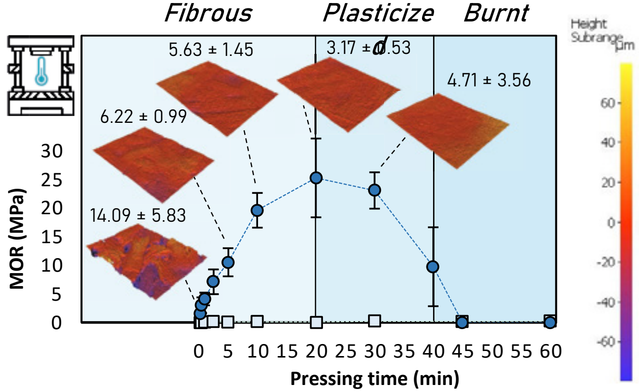
Performance	**Environmental**
Mechanical properties	Biodegradability
Thermal properties	Dry recyclability
Surface roughness	Fragmentability
Water resistance	LCA

Results

Mechanical properties as function of process parameters



Three distinct material states



Amélie LEFEVRE

Ph.D. fellow (2023-2026)
LGP2 (N. Marlin; G. Mortha)
CERMAV (L. Heux)

Upcycling of recycled fibres by oxidative processes

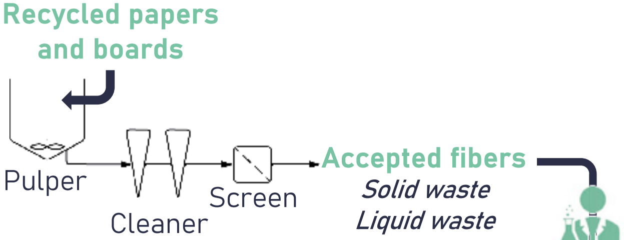
Amélioration des fibres recyclées par procédés d'oxydation

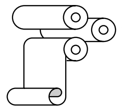
BioChip

Context / Objectives

PEPR **PAC3R** « Recycling, Recyclability, Re-use of Paper and cardboards »

- Add more value to paper and board recycling products
- Recycle all types of paper and board
- Valorize recycling waste





Limit the use of additives and virgin fibers and ensure paper quality

To develop new sustainable chemical process to upcycle recycled fibers for packaging applications

Funded by: anr agence nationale de la recherche; France 2030 Programme de recherche Recyclage

Methods

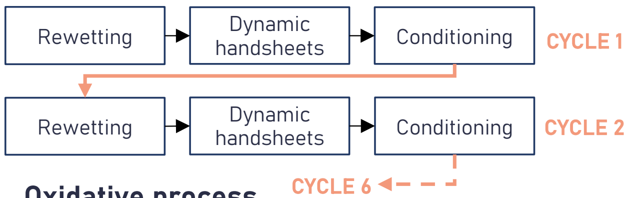
Enhance the fiber's bonding potential to improve paper's mechanical properties and resistance to water

Raw materials

Test Liner
Recycled fibers
Contaminants
Fillers

Refined UKP
Softwood Kraft pulp, high kappa
Contaminant-free

Recycling at laboratory scale



Oxidative process

CHO or COOH groups creation on lignin to increase its hydrophilicity and increase fiber bonds

Ozone treatment
High fibrous consistency, acidic conditions

Grafting process

Chemical and mechanical characterizations

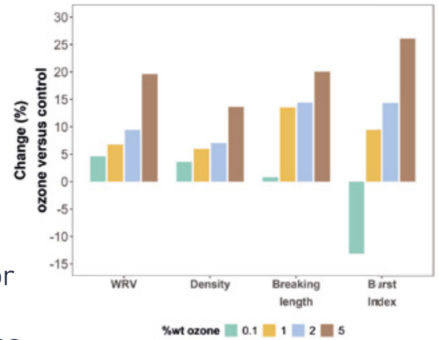
DP_v, Kappa number, COOH content
Water Retention Value (WRV), Tensile, Burst

Results

Test Liner

Improvement
5% - 20% of mechanical properties

Presence of contaminants
⇨ difficulties for chemical characterizations



Cycle 3 refined UKP

Recover 20 to 45% of mechanical properties lost through 3 successive recycling operations while **preserving lignin and cellulose**

Property	Recovery percentage
WRV	36
Density	46
Breaking length	22
Burst index	31

$$\text{Recovery percentage} = \frac{\text{Property gain on cycle 3 due to ozone}}{\text{Property loss due to 3 times recycling}}$$

	Control	Ozone
DP_v	1763	1438
Kappa number	87	55

Maxime LEGAY
Ph.D. thesis (2023-2026)
LGP2 (D. Beneventi;
I. Desloges, J. Viguié)

Printing stiffeners on the surface of folding or corrugated boards: a bio-inspired approach to lighten packaging and optimize resource consumption

Impression de renforts à la surface d'emballages cartons: une approche bio-inspirée pour alléger les emballages et optimiser la consommation des ressources.

MatBio FunPrint

Context / Objectives

Paper industry consumption

- 15-25 m^3 of water / ton of paper
- 2.9 kWh / ton of paper
- 2-3 ton of wood / ton of paper

Two approaches to reduce the use of resources :

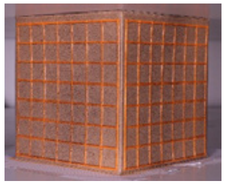
1. Lighten packaging
2. Increase the use of recycled pulps in packaging

→ **But how to keep good mechanical performances ?**

3D printing polymer ribs on cardboard packaging boxes

Ribbed structures = high bending stiffness to weight ratio → Printing polymer ribs on cardboard is a promising idea to increase packaging strength adding a reduced weight

- **Finding a suitable deposit material** :
  - → 3D printability
  - → Environmental impact
  - → Mechanical performances
- **Characterizing** the behavior of printed cardboard
- **Optimizing** the geometries of the ribs patterns to maximize the strength to weight ratio

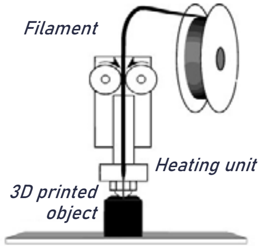


Funded by: UGA Collège doctoral, ED I-MEP²

Methods

3D Printing

- **PLA** used as a demonstrator printed by Fused Deposition Modelling = 3D printing from a solid filament
- Ongoing work on **cellulosic paste** cold extrusion



Mechanical characterizations

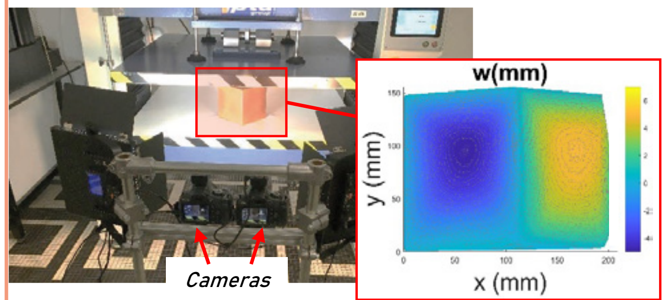
Comparison of printed and unprinted cardboard by :

→ **4 points bending** of plates

→ **Compression tests** of boxes

Monitoring the boxes' deformation

→ **Digital Image Correlation (DIC)** to measure the displacement fields of the boxes' surfaces during compression tests



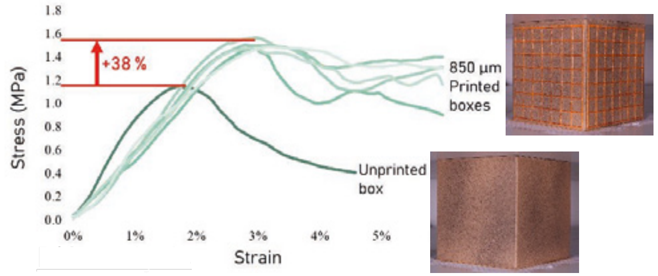
Results

Improvement of the mechanical performances

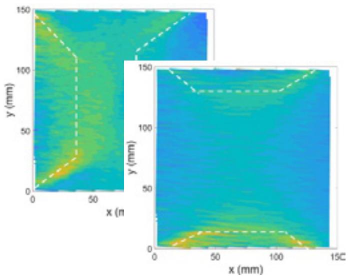
By printing 850µm thick PLA grids :

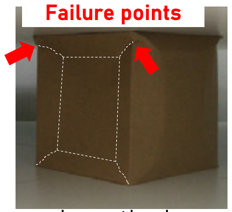
→ **Bending stiffness x2** in CD & **x 1.5** in MD for + 50w%

→ **Compression strength +40%** for +20w%



Deformation maps of the panels before the rupture highligth some critical zones…





…where the box finally fails

→ **Predictive information to improve ribs patterns**

Julie LUNEAU

Ph.D. thesis (2023-2026)
LGP2 (R. Passas; C. Martin)

Influence of the drying conditions on the surface properties of end-products during Roll to Roll surface functionalisation : comparison between copper and fiber-based strips

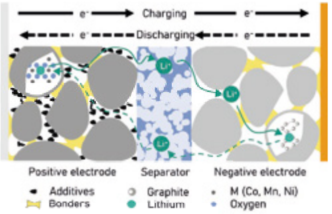
Influence des conditions de séchage sur les propriétés de surface des produits finis lors de la fonctionnalisation de surface Roll to Roll : comparaison entre les bandes à base de cuivre et de fibres

BioChip
MatBio

Context / Objectives

Context : Lithium-ion battery

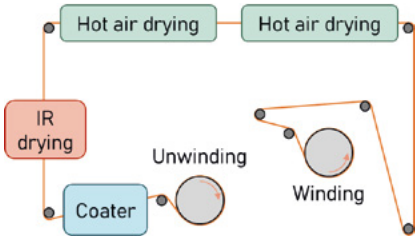
- Need to store energy produced
- production increasing of electrical cars
- Need to improve the manufacturing process



Schematic drawing of the components and operation of a lithium-ion battery cell – Marcel Schmitt

The electrodes are manufactured by coating an active material on the current collector, copper, for the negative one.

Objectives : Adaptation of a paper functionalization driver for lithium ion battery negative electrode manufacturing.



Schematic drawing of the functionalization driver

Funded by:
AMI – CMA, L'école de la batterie, Grenoble-INP UGA

edlb+ L'école de la batterie
GRENOBLE INP UGA

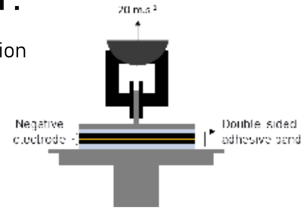
Methods

Slurry characterisation :

- 2 slurries formulations
- Rheological characterisation
- Surface tension measurement

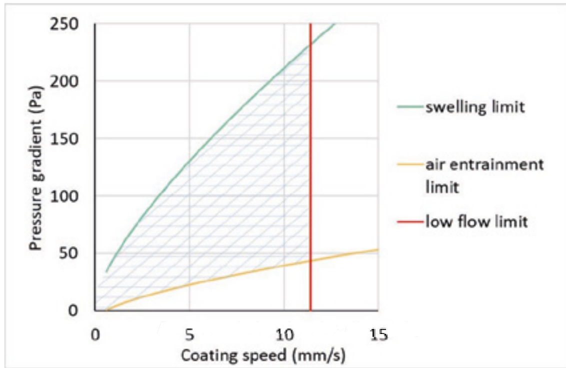
Copper film characterisation with and without functionalisation :

- Electrical characterisation
- Electrochemical characterisation
- Surface characterisation
- Thermal characterisation
- Mechanical characterisation
- Adhesion to the substrate



Tensile adhesion test

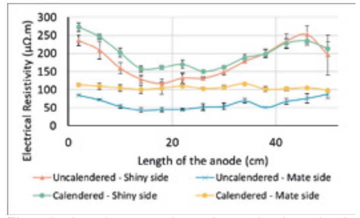
Slot die coating :



Copper temperature simulation on the driver.

Results

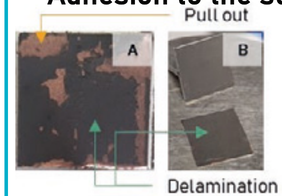
Electrical resistivity :



Electrical resistance along the entire length of a negative electrode (cross direction of production)

- The glossy side is less conductive than the matte side.
- Calendering does not improve the conductivity of the layer.
- Presence of edge effect for the glossy side.

Adhesion to the substrate :

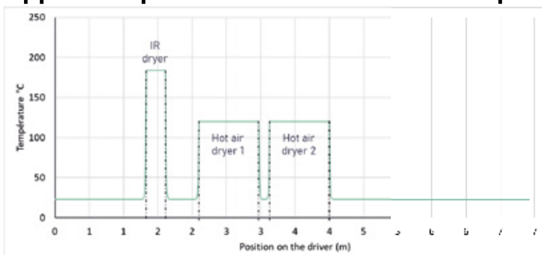


Electrode delamination after tensile adhesion test on A) uncalendered and B) calendered electrode

	Pull-out	Delamination
Uncalendered	→	→
Calendered	X	→

- Uncalendered electrodes : shiny side is more adhesive.

Copper temperature simulation on the pilote



Modeling the evolution of copper temperature in a steady-state condition throughout the driver.

Zelda MONTEIL-OCHS
Ph.D. thesis (2023-2026)
LGP2 (D. Beneventi)
STPE - CEA Liten (G. Furia ;
JF. Blachot ; M. Heitzmann)

Development of conductive bio-based composites for printed PEMFC

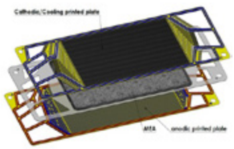
Développement de composites biosourcés conducteurs pour les PEMFC imprimées

FunPrint

Context / Objectives

Printed PEMFC* developed by CEA

**Protonic exchange membrane fuel cell*



Advantages of printing: lightweight, compact, roll to roll industrialization, flexible in implementation.

Printed bipolar plates in PEMFC

Printing of fluidic channels to distribute gases and cooling, conduct electrons, water management and mechanical strength of the cell

Carbon composites printed on carbon coated foils
But based on harmful fluoropolymer incompatible with potential European legislation

Objective : Replacing the fluoropolymer in the composite with a bio-based polymer

Composite specifications

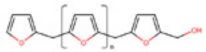
- Composition: bio-based binder + carbon fillers
- Resistant in PEMFC environment: resistant to heat (80 °C), water/moisture and acids (pH = 3)
- Electrical conductivity > 100 S/cm and Areal specific resistance < 0.01 Ω.cm² and low deformation under 1 MPa

Funded by: cea liten

Methods

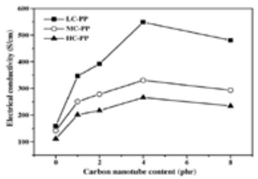
Biobased polymeric bider compatible with PEMFC environment, with printing processes, and good resistance to heat, carbonization potential:

Polyfurfurylic alcohol (PFA)



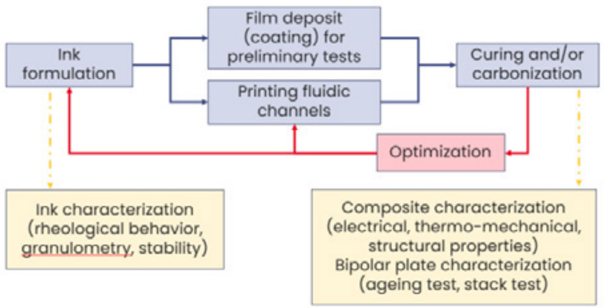
Carbon fillers to provide electrical conductivity to composite. Multi-charge composite to increase the number of percolation paths and create a maximum for conductivity:

Graphite (G) + Carbon Nanotubes (CNT)



Conductivity for bipolar plate: optimum for 20%wt PP binder, 80%wt G and 4 phr CNT (Liao and al. 2008)

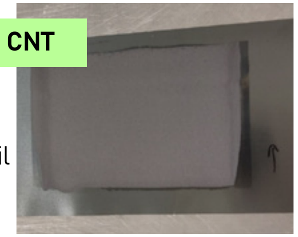
Process and characterization



Results

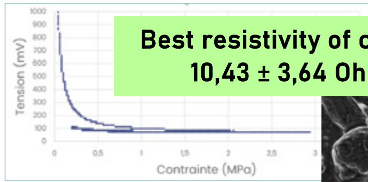
1) Ink formulation

PFA + G + CNT

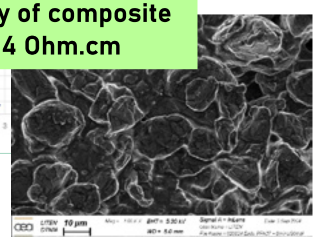


2) Film coating on carbon foil
+ Cured 90°C – 130°C

3) Composite characterization

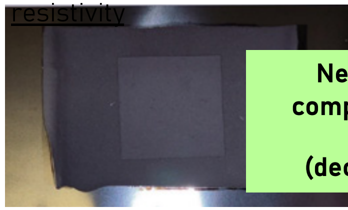


Best resistivity of composite 10,43 ± 3,64 Ohm.cm



SEM structural observation

4) Carbonization treatment to reduce the resistivity



New resistivity of composite 1,63 ± 0,30 Ohm.cm (decreases by 84%)

Chloé PARISI
Ph.D. thesis (2023-2026)
LGP2 (J.Bras)
SIMAP (E.Blanquet) / CILKOA

Atomic Layer Deposition (ALD) optimization into cellulosic substrate for barrier properties

Optimisation du traitement ALD sur supports cellulosiques

MatBio

Thèse confidentielle

Context / Objectives

New legislation on plastic packaging

Reduce Reuse Recycle

- Single Use Plastics Directive (2019)
- Packaging and Packaging Waste Regulation (2018)

Green alternative

Cellulosic materials

Abundant, Recyclable, Biodegradable & Renewable

☒ Permeable, Low barrier & Hydrophilic

CILKOA

Develop an innovative hydrophobic barrier treatment for cellulose substrates with few nanometers of ceramic

Objectives

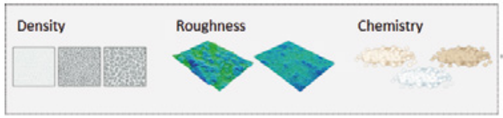
☐ Study the influence of substrate density, roughness and chemistry on ALD deposition
☐ Study adhesion of different layers
☐ Determine converting resilience for specific applications

Funded by: RÉPUBLIQUE FRANÇAISE, ADEME

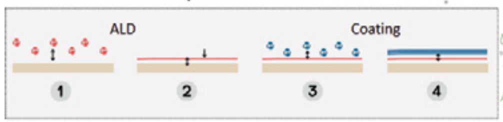
In collaboration with cilkoa

Methods

WP 1 Influence of cellulosic structures



WP 2 Adhesion phenomena



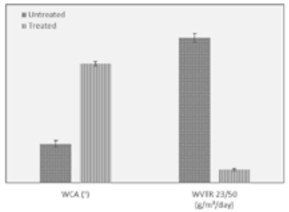
WP 3 Converting & Applications

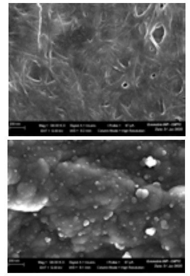
Characterizations

Properties: Water Vapor, Water, Oxygen, Fire resistency…
Ellipsometry, X-Ray Fluorescence, ICP-MS, SEM-FEG, AFM…

Results

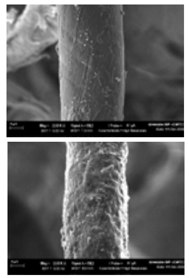
On paper…

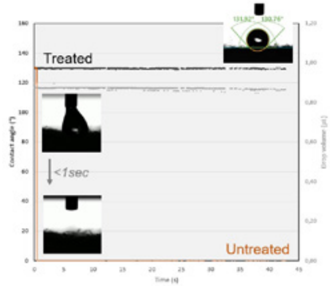


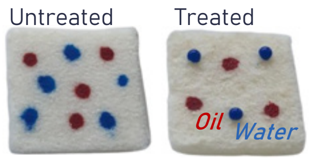


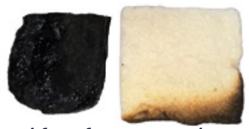
☑ Good barrier properties

On foam…









After few seconds

☑ Hydrophobic, Selective absorption & Fire retardant

Panagiota RIGOU

Ph.D. thesis (2023-2026)
LGP2 (N. Marlin;
G. Mortha; D. Lachenal)

Clean process for dissolving wood cellulose for the production of textile yarn

Procédé propre de dissolution de cellulose de bois pour la production de fil textile

BioChip

Context

Dissolving pulps

- Expanding market for dissolving pulp (textile production, cellulose derivatives and nanocellulose)
- Wood pulp or cotton linters with high cellulose content (>90 %) and distinct properties
- Main methods to obtain dissolving pulps: Kraft pre-hydrolysis (PHK), and acid bi-sulphite (AS)

Regenerated cellulose

- Chemically modified cellulose deriving from dissolving pulps or cotton linters
- Cellulose derivatives that can be obtained: viscose, lyocell, cupro and acetate

Natural fibers

- Viscose: polluting production process (use of CS_2)
- Lyocell – Cupro: expensive production processes
- Cotton: high consumption of water, demand for more arable land, use of pesticides

Synthetic fibers

- Fossil-based derivatives
- 64 % of the global fiber market
- Release of microplastics even if recycled

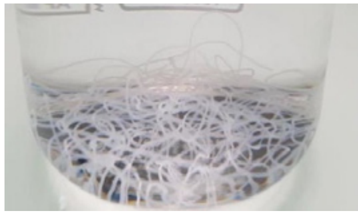
Funded by: Grenoble INP UGA, anr

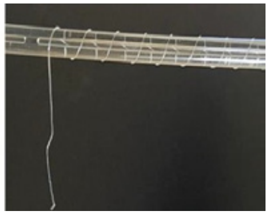
Project in collaboration with CTP, UniLaSalle, Gemtex

Objectives

Optimization of cellulose oxidation and dissolution to produce textile yarns

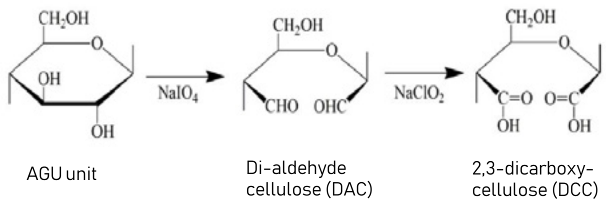
- Optimization of $NaIO_4$ – $NaClO_2$ oxidations to produce oxidized cellulose with high amount of COOH groups and without severe degradation of DPv
- Enhancement of cellulose dissolution in alkaline medium
- Increase cellulose accessibility by using pre-treatments (mercerization, mechanical refining, high consistency mixing)
- Recycling of $NaIO_4$, replacement of $NaClO_2$ to chlorine free oxidant
- Regeneration of dissolved cellulose to yarns with properties comparable to viscose yarns





Methods

Two-step oxidation, $NaIO_4$ – $NaClO_2$



Cellulose dissolution → **Regeneration of dissolved cellulose to yarns**

Chacterization methods :

- Carbonyl (HCO) measurement by titration
- Carboxyl (HCOOH) content by conductometric titration
- Viscosity – degree of polymerization (DPv) of the oxidized cellulose
- Dissolution yield

Suzy RUANO

Ph.D. thesis (2024-2027)
LGP2 (J. Bras ; N. Belgacem)
Gascogne Paper (J. Desmaisons; A. Pinsolle)

Development of new biobased barrier solutions for flexible packaging

Développement de nouvelles solutions barrières biosourcées pour emballages flexibles

MatBio

Thèse confidentielle

Context / Objectives

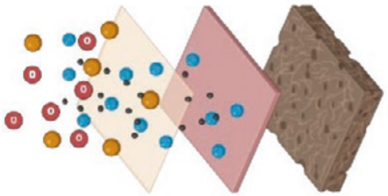
Regulations

SUP directive – AGEC law – PFAS regulation

- Imminent need to find **plastic and PFAS – free** solutions
- Solutions such as petro-based coatings or laminated papers are emerging, but at **detriment of the packaging's end-of-life.**

Challenges

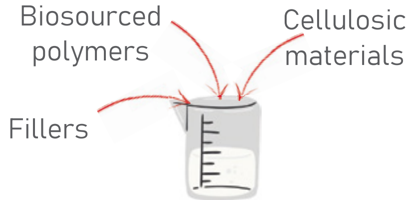
- Formulation of 100% biobased solution
- Optimize and adapt coating processes
- Improve and adapt barrier characterization methods



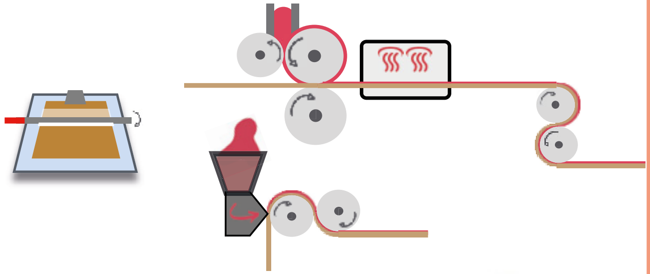
Funded by: Gascogne – ANRT Association Nationale Recherche Technologie

Methods

Formulation



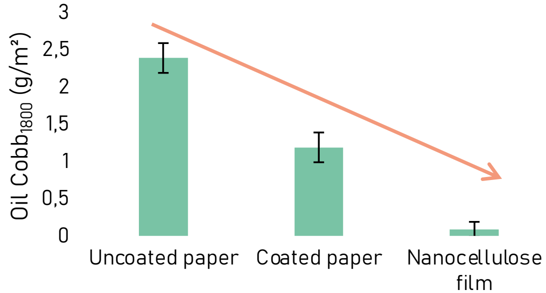
Coating processes : from lab to pilot and industrial scale devices



Barrier characterization

Results

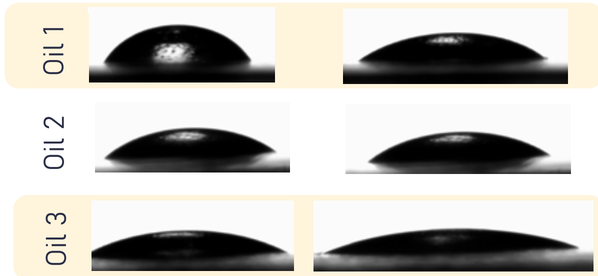
Oil Cobb measurements

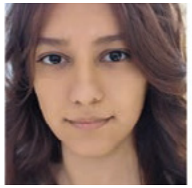


Liquid oil behavior onto paper substrate

→ Depending on the oil used, the substrate doesn't react the same way

→ Each oil has its own characteristics: viscosity, surface tension, density





Niusha SAFARI

Ph.D. thesis (2023-2026)
LGP2 (C. Chirat)
TIMC (B. Toussaint; D. Hannani)

Study the Nature of Wood Oligosaccharides for their Prebiotic effects

Étude de l'effet de la nature des oligosaccharides d'hémicelluloses de bois sur leurs propriétés prébiotiques

BioChip

Context

The establishment of biorefineries is crucial for enabling integrated production of food, feed, chemicals, materials, fuels, and energy in the future.

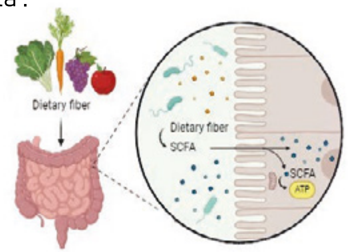
Hemicelullose valorization

valorizing hemicellulose plays a crucial role in maximizing:

- resource utilization
- diversifying product streams
- reducing waste
- promoting sustainability in biomass processing industries.

Prebiotics

Due to their structural resemblance to common dietary fibers, wood-based oligosaccharides exhibit prebiotic characteristics, providing advantageous effects on the host's health by selectively influencing the composition of the gut microbiota[1].

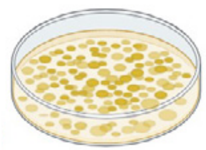


Funded by: GRENOBLE INP UGA; UGA COLLÈGE DOCTORAL ED I-MEP²

Objectives

- **Purification and characterization of the Oligosaccharide solution's fractions with the possibility of having an immunomodulatory effect**

- **Finding the most relevant microbial consortium and system to initially screen the fractions**

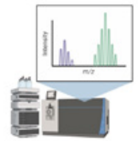


- **Study the promising fractions *in vivo*, to evaluate the immunomodulatory effect of the fractions**

Methods

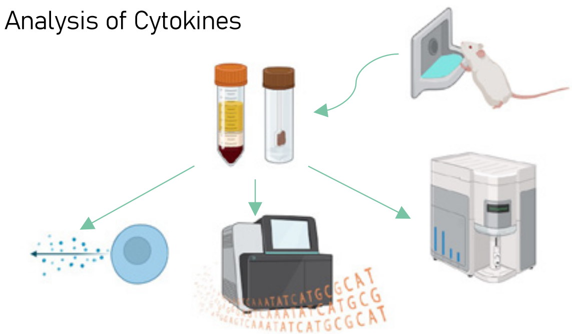
Oligosaccharides purification and characetization

- Ultrafiltrartion
- HPLC
- FTIR
- MALDI ToF



Prebiotic tests including *in vivo* and *in vitro*

- SCFA analysis
- Flow Cytometry
- Metagenomic study of caecal microbiot
- Analysis of Cytokines



Graphics created with BioRender.com

1.La Rosa, et al.(2019). Wood-derived dietary fibers promote beneficial human gut microbiota. MSphere, 4(1), 10-1128.

Alicia TESTON
Ph.D. thesis (2023-2026)
LGP2 (C. Chirat; N. Marlin)

Biorefinery integrated in paper/board recycling : extraction of starch from recycled cellulosic fibers and its valorization into high value-added products

Bioraffinerie intégrée aux recyclage des papiers et cartons : extraction de l'amidon des fibres cellulosiques de récupération et sa valorisation sous forme de produits à haute valeur ajoutée

BioChip

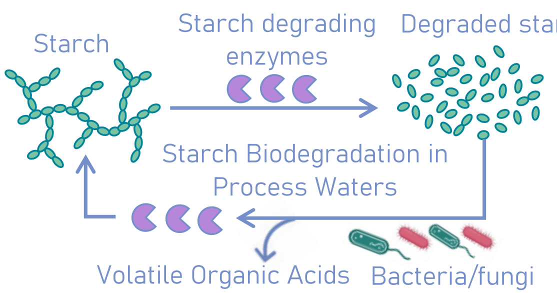
Context

Use of Starch in Papermaking

- Versatile additive : dry strength agent, retention aid, coating binder, adhesive for corrugated boards
- The paper industry consumed 1.6 million tons of starch in Europe in 2023, according to CEPI

Issues Related to Starch

- When recycled papers/boards are used to produce new paper/board grades, part of the starch contained in them ends up in the process waters, leading to microbiological, process and environmental issues

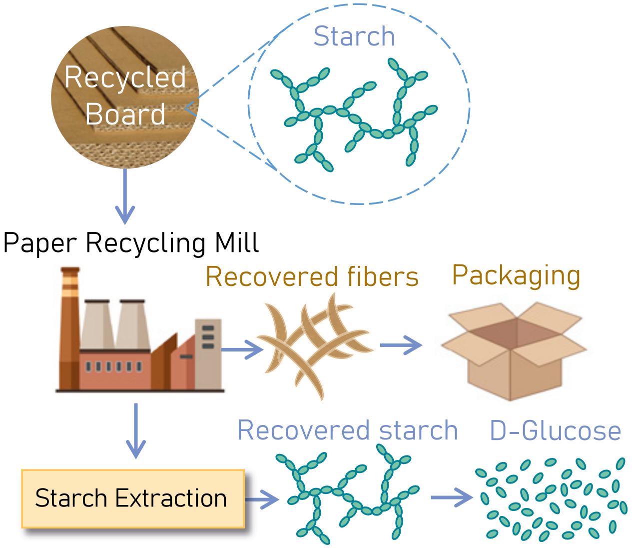


Funded by: FRANCE 2030, anr

In collaboration with UniLaSalle Institut Polytechnique

Objectives

Development of a Starch Extraction Process at the Beginning of Paper/Board Recycling Operations

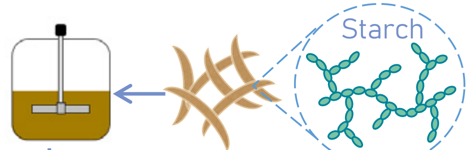


Development of a bioeconomy-compliant approach to :

- ✓ Minimize the amount of starch released in process waters during papermaking operations
- ✓ Valorize starch (considered up to now as a contaminant) into high value-added products

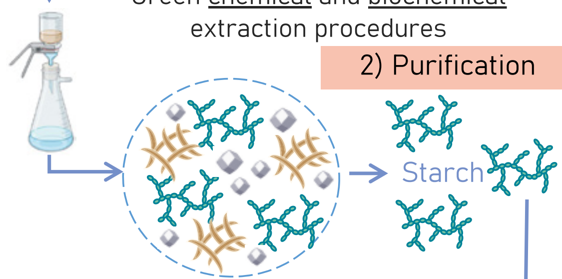
Methods

1) Extraction of Starch from Recycled Fibers



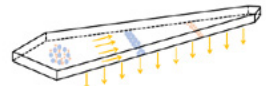
Green chemical and biochemical extraction procedures

2) Purification



Separation of starch from other soluble products using membrane filtration

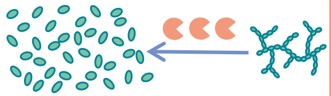
3) Characterization



Determination of the macromolecular features of the recovered starch using AF4-MALS-dRI

4) Depolymerization

Enzymatic hydrolysis of starch into D-Glucose



Arthur VALENCONY
Ph.D. thesis (2023-2026)
LGP2 (G. Mortha; N. Marlin)
FCBA (S. Tapin-Lingua)

Lignocellulosic biorefinery: Development of a new pulping process to produce high-quality fibers from underexploited resources

Bioraffinerie lignocellulosique : Développement d'un nouveau procédé de mise en pâte pour la production de fibres de haute qualité à partir de ressources sous-exploitées

BioChip

Context / Objectives

Underexploited biomass:
Huge quantities are available

- Wastes of industrial biomass
- Underexploited sources: hemp, nettle and poplar residues available in local areas

The Kraft process is a strongly alkaline process
Large plants with limited flexibility

- Soft alkaline pulping processes are in the trend
- Total Chlorine Free (TCF) bleaching sequence is a must
- Smaller cooking units for smaller biomass quantities

MicroFibrillated Celluloses (MFC) are in current development for their good properties

- Reinforcement in composites
- Packaging applications for barrier properties
- Textile utilization

Funded by: FCBA INSTITUT TECHNOLOGIQUE, Cifre, ANRT, Bio-LUSH

Methods

Process – at lab and/or pilot scale


Selection of wood
→

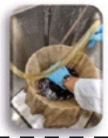
Bark
+

Wooden log
→

Wood chips

xylem · Empa Materials Science and Technology · FCBA

←

Soft alkaline Cooking
←

Washing
←

TCF bleaching sequence

↓


Refining
→ Ready-to-used pulp →

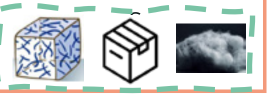
Properties
- Mechanical
- Optical
- Barrier

↓


MFC production
→

MFC suspension
→

Properties
- Morphology
- Rheology
- Mechanical
- barrier

Application


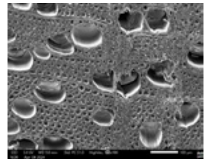
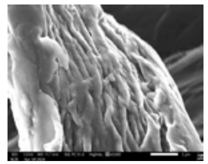
Results

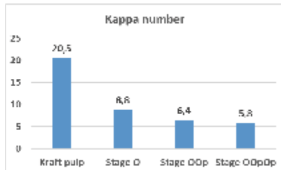
Analysis of 5 poplar species
- Chemical composition
- Fiber morphology

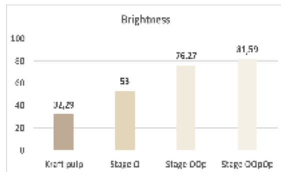
→ **One species selected**

↓
Kraft cooking
↓
TCF bleaching

Studying the diffusion of chemicals into wood chips



SEM images

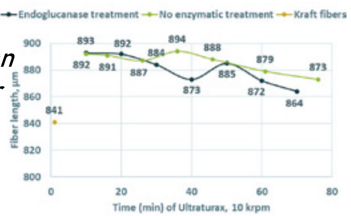




Evolution of properties at each stage

↓
Endoglucanase treatment
↓
Ultraturax treatment → MorFi

Evolution of fiber length



Emma COLOMBARI
Ph.D. thesis (2022-2025)
LGP2 (J. Bras)
CRAterre (T. Joffroy, A. Misse)

DESICELL : Design approach for new recyclable cellulosic based materials in building industry

Nouveaux procédés d'obtention de matériaux cellulosiques et terre crue recyclable en architecture

MatBio

Context / Objectives

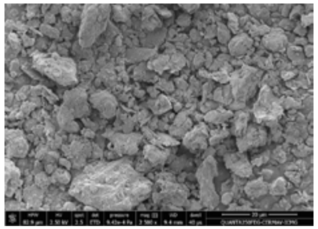
Building sector is very polluting

- 23% of the French carbon footprint[1]
- 60% CO_2 emission of building : finishing elements[2]

References:
1. *Ministère de la transition écologique – 2022*
2. *OID - Penser l'immobilier responsable - 2019*

Reversible earth-fibers based panels

- Raw earth coming from quarry waste: washing sludge, rich in silts and clay: slightly cohesive.
- Cellulose fibres coming from virgin or recycled fibres: eucalyptus or old newspapers.
- Producing cohesive, hygroscopic and flame retardant materials for finishing elements.



MEB: Raw earth

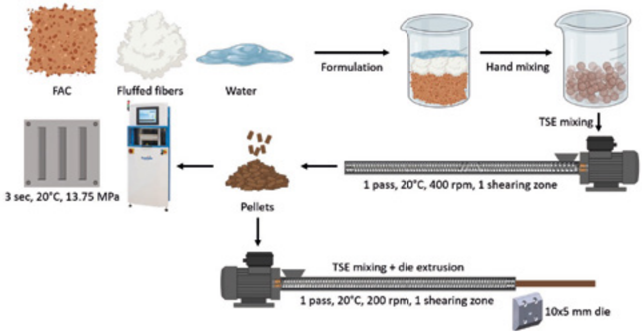
Microscope: eucalyptus fibres

In collaboration with: CRAterre

Funded by: Glyco@Alps Université Grenoble Alpes; France 2030

Methods

Panels production process



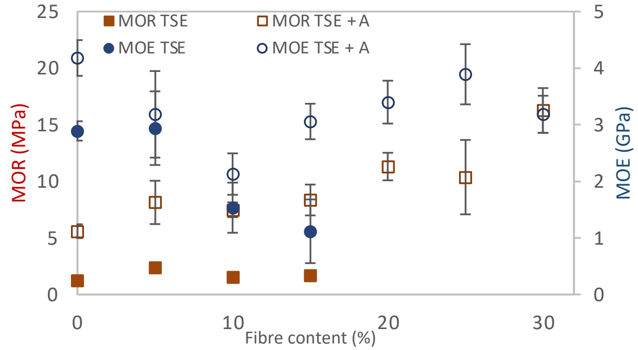
- Formulation with various fibres content and water (+ bio-based additive).
- Mixing process is done using a twin-screw extruder with one shearing zone.
- Samples are produced using compression or extrusion. Leading to very different final materials.
- Compressed and extruded samples are then dried at room temperature for 5 days.

Compressed sample

Extruded sample

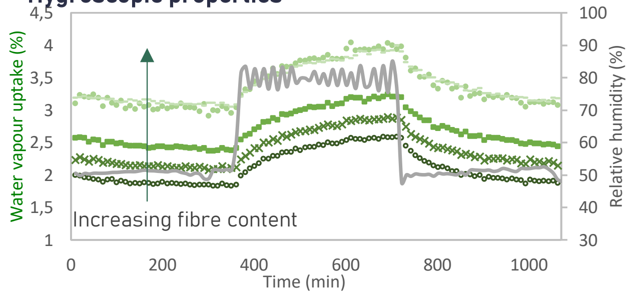
Results

Mechanical properties



The addition of bio-based additive improves significantly the mechanical properties.

Hygroscopic properties



Addition of fibres increases the water vapour uptake. This can have a potential application for indoor humidity regulation.

Mathilde DAVID
Ph.D. thesis (2022-2026)
LGP2 (Q. Charlier, J. Bras)

Manufacturing of bio-based materials using ultra-sonic compression molding

Élaboration de matériaux biosourcés par compression ultrasonore

MatBio

Context / Objectives

Manufacturing of 100% biosourced materials

Environmental footprint reduction

Bio-sourced materials can have a significant environmental impact :

- Use of petroleum-based resins (wood panels)
- High energy consumption during production (papers and boards)
- Low recyclability (bio-based composites)

New process and material development

1. Use of Bio-waste as raw material in order to get into a *circular economy model*
2. Dry process in order to *reduce water and energy consumption*
3. Manufacturing of molded composites via powder compression using ultrasonic vibrations

→ 100% Composite materials made derived from cellulosic fibers and natural binder (lignin and others)

Funded by: GRENOBLE INP UGA; UGA COLLÈGE DOCTORAL ED I-MEP²

Methods

Ultrasonic compression

High frequency acoustic vibration under compression

Compaction of dry powder into bulk Composites materials

Figure : Ultrasonic Press - Sonimat

Characterization methods

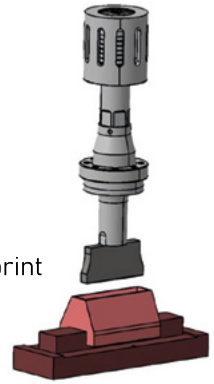
Analysis :

- Microstructural

- Resistance to water and humidity

- Mechanical properties

- Energy consumption



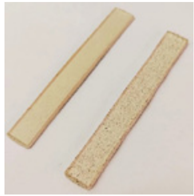
Impact assessment

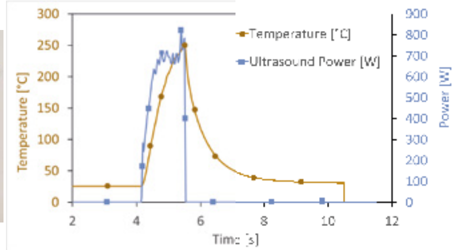
- Multicriteria analysis to associate material properties and energy footprint
- Toward scale up (TRL 4+)

Results

Key process parameters :

- Power and transmitted energy
- Pressure

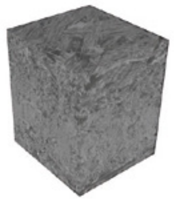




Process development :

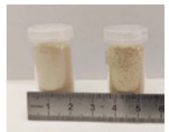
- Molds (for dry materials)
- Spring tooling system for US molding
- Temperature monitoring

In-situ monitoring of material formation



Key raw material characteristics :

- Influence of chemical composition
- Shape and Size of bio-elements
- Influence of humidity content



Conference:
David M. Et al. (2023), Journée Nationale sur les Composites (JNC). *Besançon*

Maxime FAUREAU-TILLIER
Ph.D. thesis (2022-2025)
LGP2 (A. Blayo; A. Denneulin)
Chomarat (J. Maupetit)

Modification of the properties of polymer surfaces by an environmentally friendly printable coating

Modification des propriétés de surfaces polymères par un vernis imprimable respectueux de l'environnement

Thèse confidentielle

FunPrint

Context / Objectives

Coatings industry – Textile field

Textile personnalization

- Demand used to grow up the last decade
- Customers always want new design in every area
- Clothing manufacturers are looking for new solutions

Use of a lot of dangerous products for both human health and environment

<u>Objectives :</u> Create a new coating that respects :

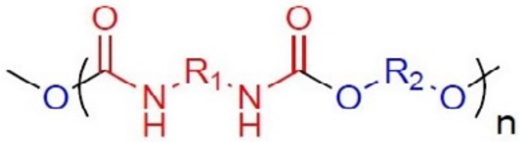
- the same requirements and industrial constraints than solvent-based product
- the environment, labels, laws and human health

Funded by: ANRT CHOMARAT

In collaboration with Chomarat Textiles Industries

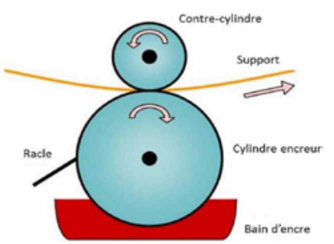
Methods

Formulation with polymer and additives



Rotogravure/reverse coating

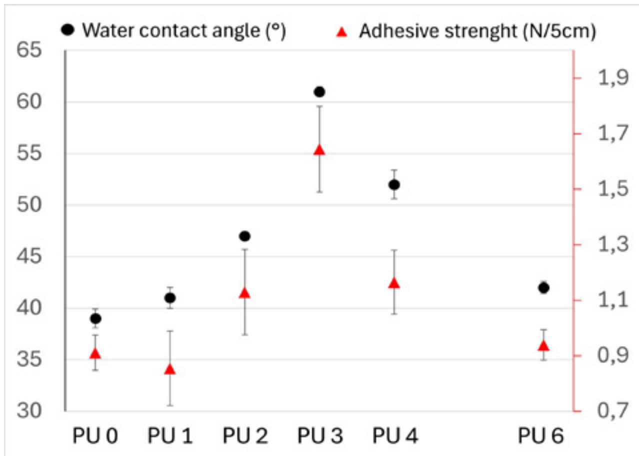
Transfert with heat and pressure on textile

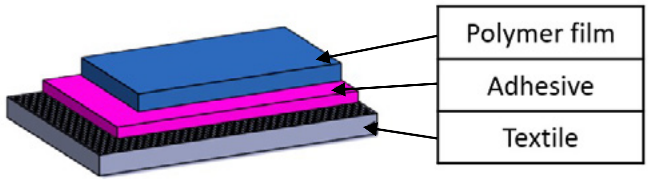


Surface/interface/interphase characterizations

- Optical/mechanical roughness measurements
- Contact angle measurements
- Chemical composition : XPS/TOF-SIMS/RMN
- Mechanical properties

Results





Marie GOIZET
Ph.D. thesis (2022-2025)
LGP2 (A.Deneulin; J.Bras)
Encres Dubuit (G.Krosnicki)

Development of stretchable conductive inks

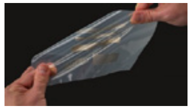
Développement d'encres conductrices étirables

FunPrint
MatBio

Thèse confidentielle

Context / Objectives

Stretchable electronics field



Growing and emerging market
Applications in :
- healthcare, safety, wearables,
- energy, automotive…

Current stretchable conductive inks :
- Are using petroleum-based elastomers (PDMS, TPU)
- Have heterogeneous performances (from one to another) and lack of characterization

Challenges:

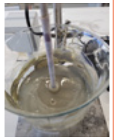
Technical
> Maintaining a functional conductive printed track under strain: adhesion, mechanical failure, electrical percolation
> Tuning ink properties to screen printing technology

Scientific
> Understanding physico-chemical interactions between ink components
> Developping tools to characterize the behavior of the printed track under deformation

Funded by: ANRT Association Nationale Recherche Technologie; Encres DUBUIT

Methods

Formulation of stretchable fluids



- Silver particles (different morphologies)
- Biobased matrix
- Water and co -solvent
- Additives

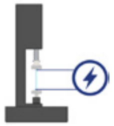
Printing process

Screen-printing

Speed: medium
90-grade mesh
Thickness : 10 µm
Substrates: TPU

Behavior of the printed track under deformation

- Monitoring electrical resistance change under deformation

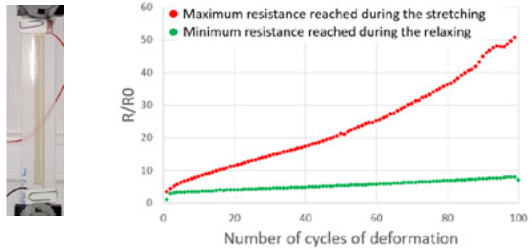


- Characterizing the mechanical deformation with Digital Image Correlation

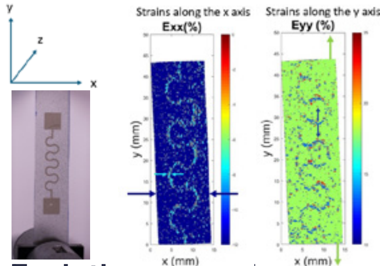
- Understanding the formation of micro cracks using tensile testing under SEM

Results

Electromechanical characterization

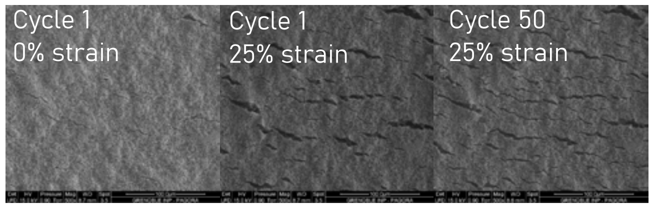


Mechanical deformation characterization



Compression along x
Extension along y

Evolution of cracks under deformation



Jérémy MANIFACIER

Ph.D. thesis (2022-2025)
LGP2 (A. Blayo; A.Boyer)
in coll. with J. de Bardonnèche

Bio4Inks: Formulation of 100% biobased 4-colored inks for press printing

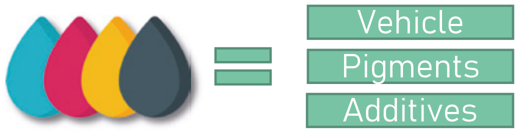
Formulation d'encres coldset quadrichromiques 100% biosourcées pour la presse imprimée

FunPrint
BioChip

Context / Objectives

Need for sustainability

Replacing petroleum-based pigments in offset inks



- Several biobased offset vehicles are already used
- Very few research on biobased pigments in inks

Finding suitable pigments for ink formulation

- Compatibility with oil-based vehicles and fountain solution
- Color strength
- Low ΔE between the new inks and the standard ones
- Stability of properties (light, pH)

Formulating inks with suitable properties

- Rheological properties
- Tack
- Permanence properties

End of life (recyclability, biodegradation)

Funded by: MINISTÈRE DE LA CULTURE, CITEO

In collaboration with Écograf, Sun Chemical & Grakom

Methods

Pigment grinding

Dry grinding using bead mill
Wet grinding using three-roll mills

Mixing

Mixing using a SpeedMixer device

Lab printing

IGT C1-5 on paper
10 successive prints
Transfer curves

Pigment characterization

- Pigment size (granulometry)
- Composition (proximate analysis)
- SEM imaging

Ink characterization

- Tack
- Rheological properties (thixotropy, viscosity)
- Colorimetric properties (optical density, color)
- Lightfastness (Xenotest)

Industrial tests

Deinking tests

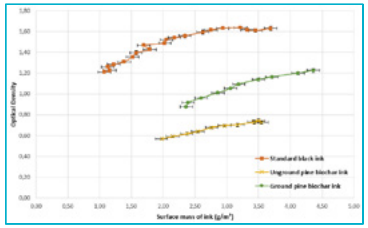
Results

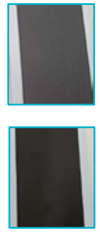
Selection of biobased pigments

Lookout for pigments through literature and known historical biobased pigments

Black inks

Inks formulated with biobased pigments (1) are lighter than standard (2) but dark enough to be readable





(1)

(2)

→ Pilot tests on progress

Colored inks

Promising results for yellow and magenta inks
Only few biobased pigments for cyan inks

→ R&D project in partnership with a supplier

Léopold OUDINOT
Ph.D. thesis (2022-2025)
LGP2 (J.Viguié)
3SR(F.Dufour; A.Naillon; L.Orgeas)

Comprehension and characterization of the impregnation and drying of bio-based hydrogel for self-folding of architectured paper structures

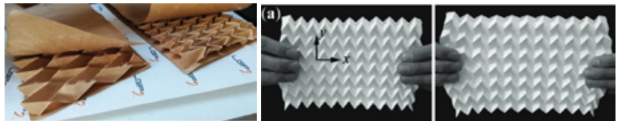
Compréhension et caractérisation de l'imprégnation et du séchage d'un hydrogel biosourcé pour l'autopliage de structures papier architecturés

BioChip

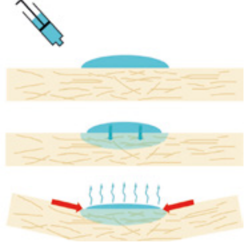
Context / Objectives

Architectured paper structures

- Developp new paper based sandwich pannel (folded core improving mechanical performances)
- Industrial production via self folding technologies



Self folding mechanism using a cellulose hydrogel



(1) Hydrogel printing

(2) Paper impregnation

(3) Drying and folding

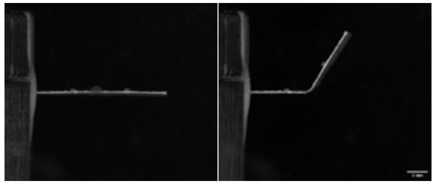
- Understand non newtonian fluid impregnation in fibrous media (2)
- Characterize stress and strain during drying (3)
- Find key physical parameters to predict angle and local curvature of fold

Funded by: GRENOBLE INP UGA; UGA COLLÈGE DOCTORAL ED I-MEP²

Methods

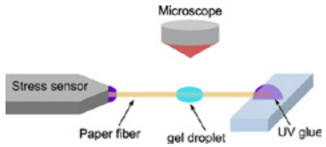
Macro-scale experimentations

Using lab paper and automatic gel dispenser



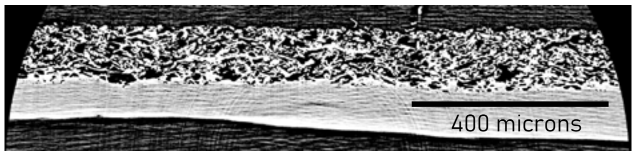
- Different papers/gels/printing parameters
- Measuring angle and curvature of fold

- **Model system approach**



- *System example*
- Separate impregnation and drying phases
- Characterise separately gel and paper behavior
- **Determine specific physical law**

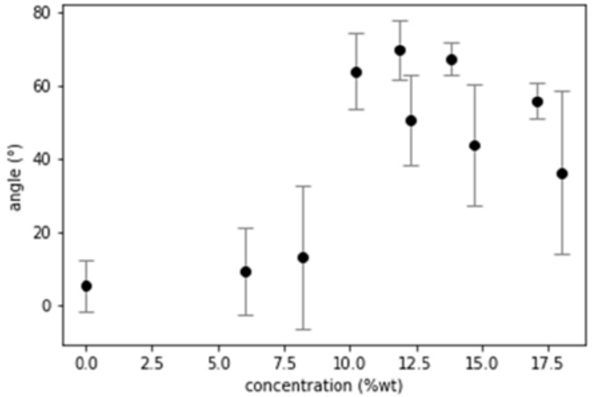
- **Meso-scale observation**



Results

Macro-scale experimentations : influence of gel concentration

- 150 g/m² bleached soft wood paper
- Dispenser delivers 0.9 mm³ of gel with 1.37mm nozzle
- Using [6 : 18]% concentrated CNC gels
- Measuring angle and curvature of samples



- The mechanism is not reliable when gels with a concentration under 8% is used
- High result variability under the same experimental conditions
- Explaining variability requires local caracterisations of paper and gel line heterogeneities

René
ROMERO LEZAMA
Ph.D. thesis (2022-2025)
LGP2 (J. Bras; I. Desloges, J. Viguie)

Development of multilayer bio-based materials for high value-added active cellulose packaging solution

MatBio

Context / Objectives

Chaire Cellulose Valley

An organisation working to:

- Upgrade cellulosic materials.
- Propose new innovative and high performance solutions.

Create a multilayer structure for active packaging.

Active layer →

- Extend shelf life product's.
- Ensure barrier properties during storage.

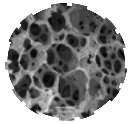
- Antimicrobial and antioxidation protection.
- Moisture protection.
- Barrier shift

Funded by: INP Fondation, AHLSTROM, Aptar, CHANEL, Marie, CITEO, DECATHLON, DS Smith, GUILLIN

Methods

Cellulose based intermediate layers

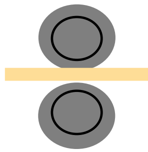
Corrugated board containing EOs



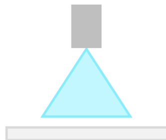
Cellulose foam containing adsorbents compounds

Processing

Preparation of active layers

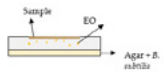


Size press impregnation

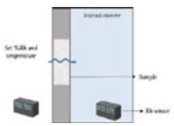


Spray

Characterization methods



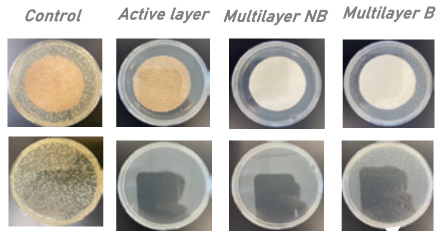
UV analysis
SPME
Microbiology test
Strawberry preservation



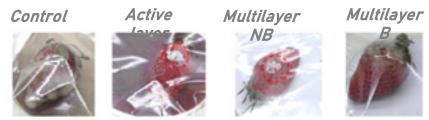
Moisture adsorption
Water vapor transmission rate
Moisture buffer capacity

Results

Controlled release of essential oils

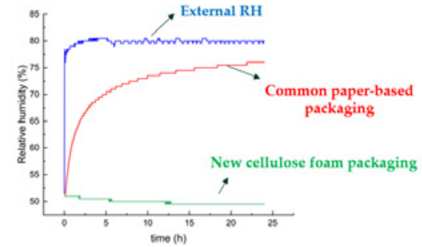


B. Subtilis inhibition



Strawberry preservation

Relative humidity control inside packaging atmosphere



Erwan TROUSSEL
Ph.D. thesis (2022-2025)
LGP2 (D. Beneventi;
A. Denneulin)
PCCEI (J-C. Brès)

Fabrication of a full-paper point of care platform by additive manufacturing

Elaboration d'un dispositif de diagnostic médical en papier par procédé de fabrication additive

FunPrint

Context / Objectives

Actual nucleic acid amplification tests (NAATs) :

- Performed in centralised laboratories
- Requires equipment and trained personnel

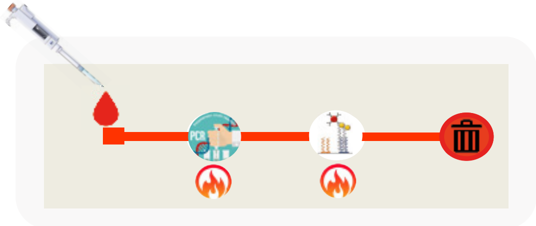
→ Bottleneck for a rapid disease diagnostic

Point of care testing (POC) :

- Defined as a test performed near or at the patient's place of residence
- Rapid results requiring minimal user intervention
- Production of plastic waste

CareFab project :

The objective is to develop a **printed microfluidic paper-based device** (µPAD) integrating all unit operations necessary for **nucleic acid amplification tests** and of the associated **fabrication process**.



Funded by: anr

In collaboration with AlpRobotic

Methods

Printing processes

6 axis robot

- Multiple printing tools :
  - Dispenser printing
  - Spray deposition
  - Jetting
- 3D substrates
- Various shape of design

Cellulose µ-particle aqueous inks:

porous cellulose based materials with high capillary suction can be elaborated using cellulose-nanofibers (CNF), -µparticles and SiO2 as inert filler obtainded by moulding

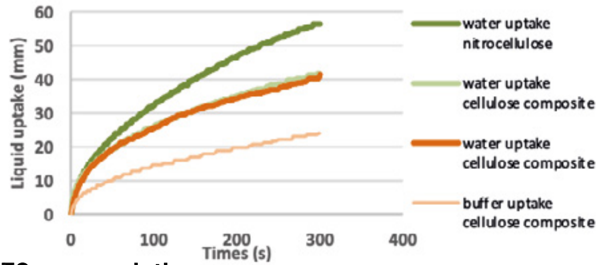
MFC spray encapsulation

Encapsulation of the path by spray of MFC to manage the air permeability. Modification of the hydrophilicity to hydrophobicity of the cellulose by addition of AKD emulsion

Results

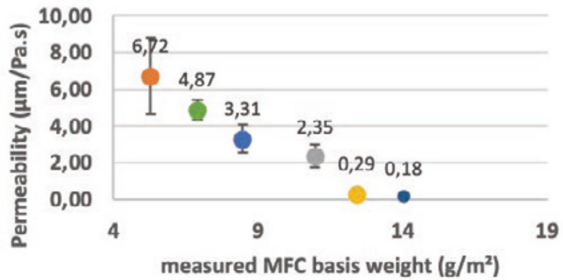
Capillarity path

- Cellulose composite with a comparable water uptake than nitrocellulose
- Increase of the accessible porosity with ethanol solvent exchange

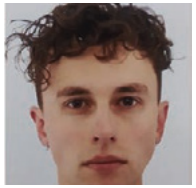


MFC encapsulation

- Decrease of the permeability with the increase of the MFC basis weight



- Increase of the water contact angle with the increase of the amount of AKD



Clément TURPIN

PhD thesis (2023-2026)
LGP2 (N. Reverdy-Bruas, J. Viguié)
3SR Lab (L. Orgéas)

Architecturing papers and boards with bio-based grid printing: a low-cost approach to lightweight packaging

Papiers et cartons architecturés par impression de renforts bio sourcés : développement d'une approche à bas coût pour alléger les emballages.

MatBio FunPrint

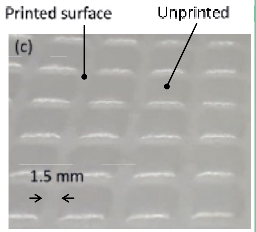
Context / Objectives

Reducing the weight of paper-based packaging

- Paper production demands substantial ressources:
  - ✓ 15-25 m^3/ton of water,
  - ✓ 2.9 MWh/ton of energy,
  - ✓ 2-3 ton/ton of wood

Idea: architecturing papers and cardboards

- Embossing paper sheets to increase their bending stiffness
- Low cost biodegradable route:
  - ✓ Printing patterns with starch suspensions
  - ✓ Sheet embossing induced during suspension drying



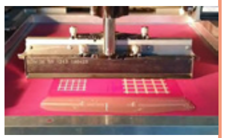
Thesis objectives

- Optimization of the printing process
- Multiscale analysis of :
  - ✓ Drying, shrinkage, buckling phenomena
  - ✓ Induced meso and microstructures
  - ✓ Induced hygro-mechanical properties

Funded by: Grenoble INP UGA, ctp centre technique du papier

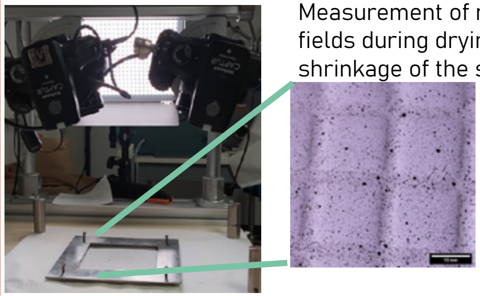
Methods

Materials & Processing route



- Handmade model paper sheets:
  - ✓ Softwood kraft bleached pulp
  - ✓ Rapid Köthen former
  - ✓ Basis weight: 80-120g/m²
- Aqueous suspension with 40 wt% of low molecular weight corn starch
- Screen printing

Monitoring the drying/embossing



Measurement of meso kinematic fields during drying and shrinkage of the starch.

Mechanical test:

Cantilever strip of paper

Bending stiffness measurement based on image analysis

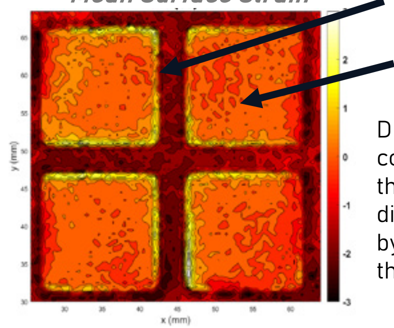
Microstructure observations :

ESEM

Results

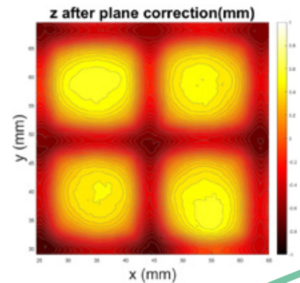
Embossing phenomenon

Mean surface strain

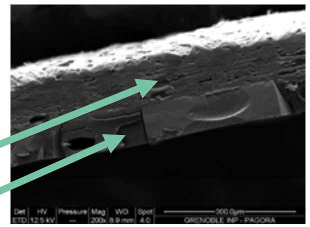


Digital Image stereo-correlation quantifies the out of plane displacement induced by the strains due to the shrinking of starch

Out of plane displacement (mm)



Structured surface shows altitude variation about 1mm. Paper is 110µm thick



Printed starch presents good adhesion, homogeneous thickness and many cracks due to its brittleness

Conferences: Turpin, C et. al. (2023). 8th EPNOE International Polysaccharide Conference, Graz

Young Researchers' research projects description

Post-doctorates and Research Engineers

Sarah ALAMI MEJJATI

Research engineer (2023-2025)

LGP2 (J.Bras, J.Viguié)

Lightweight Paper Design through Cellulose material (CM) Stiffener Printing with biomimetism

Conception de papier allégé par impression de raidisseurs en CM via le biomimétisme

MatBio FunPrint

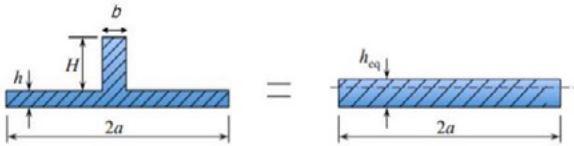
Context / Objectives

Ribbed structures for improving the stiffness to weight ratio

Objective: increase the bending stiffness with ribbed structures of CNFs with a biomimetic approach

$$D\ (bending\ stiffness) = EI$$

I = Moment of inertia

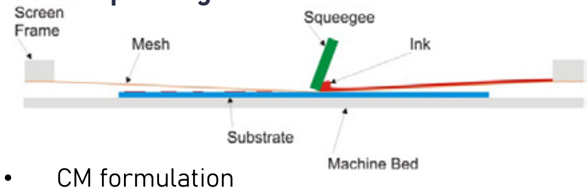


E = Young's modulus

CNF: Cellulose Nanofibrils
High Young modulus (up to 20GPa)

Methods

Screen printing



- CM formulation
- Rheology measurement

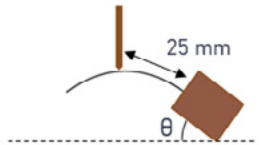
Stiffener design

Mechanical characterization

Printing → Deformation → Increase of the moment of inertia → Increase of the bending stiffness

- *Bending stiffness*

  2-point bending measurement



- *Deformation and drying shrinkage*

  Digital Image correlation (DIC)

Results

Bending stiffness

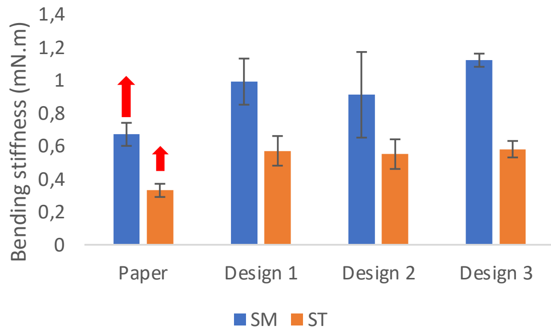
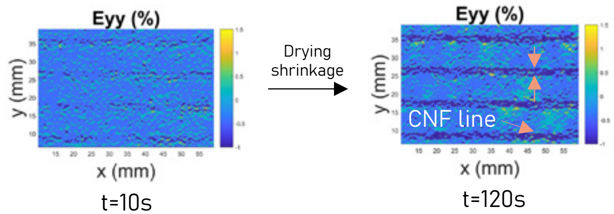
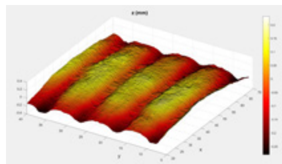


Image stereocorrelation





Increase of the moment of inertia
→ Increase of the bending stiffness

Léa CABAN

Research Engineer (2024-2025)
LGP2 (Q. Charlier)
CTP (M. Caron)

Reinforcement of cardboards and folding boxboards by ultrasonic compression

Renforcement de cartons plats et de boites pliantes par compression ultrasonore

MatBio

Context / Objectives

Cardboards :

- Widely used for packaging
- 682 kt in France and 9857 kt in Europe in 2021
- Biosourced
- Biodegradable
- 15 to 25 m^3 of water per ton of paper
- Heavier than plastic

Challenge : Reduction of density for equivalent mechanical properties

→ Reduced consumption of raw material
→ Reduced weight
→ Reduced costs

Objective :

Reinforce cardboards by locally changing their structure from fibre to composite using ultrasonic compression.

Funded by: 3SR, lgp², ctp centre technique du papier

Methods

Ultrasonic compression :

- Already known and used to seal materials together
- Low energy consumption
- Heat generation due to the combination of vibration and pressure
- Could turn a fibrous structure into a composite one by making the lignin and hemicelluloses flow around the fibres

Densification of the fibrous network :

- Structural and mechanical characterisation of the bulk material

Reinforcement of cardboards and folding boxboards :

- Local reinforcement of the fibre network by printing densified patterns
- Structural and mechanical characterisation of reinforced cartons and boxes

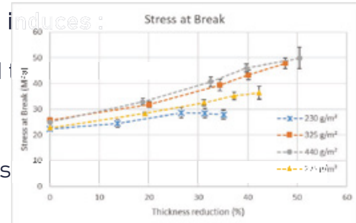
Results

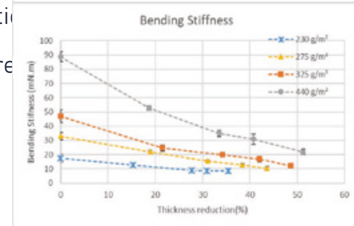
Ultrasonic compression induces :

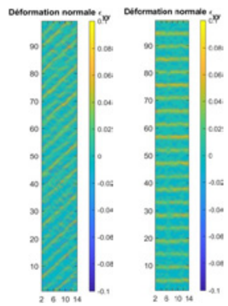
- ↗ stress at break and t
- ↘ bending stiffness
- No significant changes break

→ Successful densificati

→ No change of structure







Densified patterns drawn using ultrasounds :

- Can be used to deviate the stress inside a material under traction or compression
- Can reinforce or weaken cardboards, depending on the pattern

Jules DE BARDONNECHE
Research engineer (2023-2025)
LGP2 (A. BOYER)

BIO-4-INKS: Life Cycle Assessment (LCA) of 100% bio-based inks for newspaper offset printing

Analyse de cycle de vie d'encres 100% bio-sourcées pour l'impression offset de la presse

BioChip FunPrint

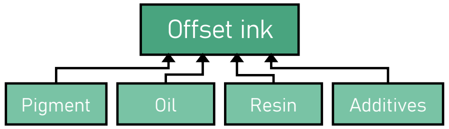
Context / Objectives

Context

- Limited recent available LCA data to guide industrials in their eco-design approach
- Environmental impacts of newly-used bio-based vehicles are little studied
- Bio-based pigments are being studied as substitutes for conventional petroleum-based colorants

Objectives

- LCA modeling of both conventional and 100% bio-based inks formulations in the European context



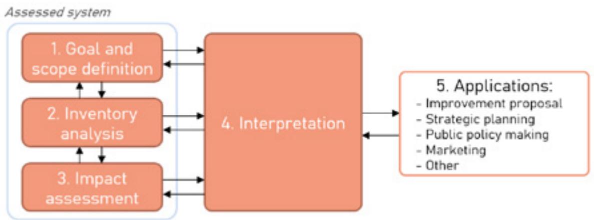
- Calculation of the environmental weight of pigment in current industrial offset ink formulations
- Impact transfer assessment through comparative LCA
- Identification of possible future improvements

Funded by: MINISTÈRE DE LA CULTURE, CITEO

In collaboration with Écograf, SunChemical, Grakom

Methods

System definition



LCA framework (ISO 14 044)

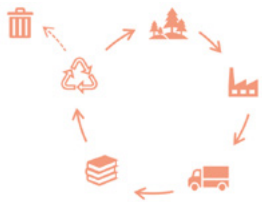
Data collection

Primary data

- Industrial partners

Secondary data

- Ecoinvent
- Literature review



Conjunction with lab work and choice of FU

- Bio-based pigments: technical relevance of assessed solutions are validated in lab environment
- Functional Unit (FU) is linked with the optical performances (contrast, color, i.a.) of the formulated inks.

Need for multi criteria approach

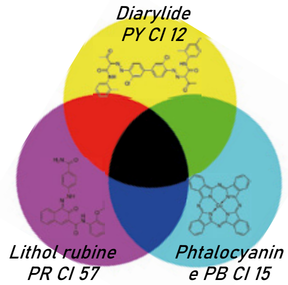
LCA method: Environmental Footprint V3.1

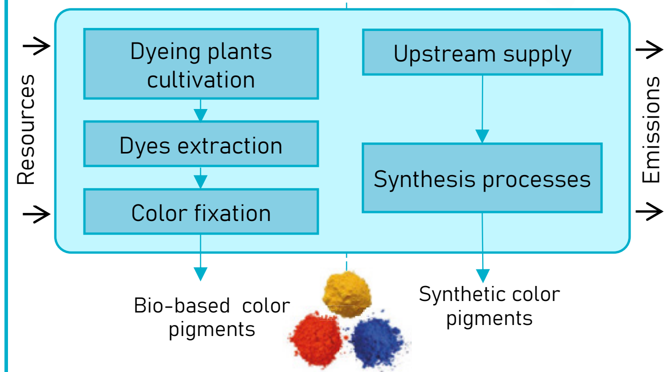
Results

Color pigments: LCI modeling and impact assessment comparison of CMY pigments

Bio-based pigments

Synthetic pigments





Alexis SUCHET

Study engineer (2024-2025)
LGP2 (J. Bras)

Development of new cellulose high-performance rigid packaging prototypes

Développement de nouveaux prototypes d'emballages rigides et performants à base de cellulose

MatBio

Confidentiel

Context / Objectives

Laws banning petroleum based plastics:

- SUP (Single Use Plastic) legislation [2018, EU]
- (Anti-Gaspillage pour une Economie Circulaire) law [2019, France]
- PPWR (Packaging and Packaging Waste Regulation) [2022, EU]

Alternative material: Cellulose

- Bio-based and biodegradable
- First in the ranking of polymers produced by nature
- Well established production and recycling

Chaire Cellulose Valley

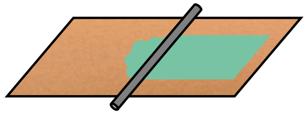
- Dedicated to the development of environmentally friendly packaging
- Connecting research, eduction and industry across the cellulose packaging value chain

Funded by: Fondation Grenoble INP, CHANEL, DECATHLON, Marie, DS Smith, CITEO, AHLSTROM, Aptar, GUILLIN

Methods

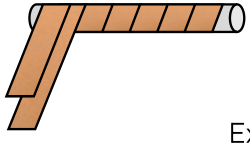
Functionalization

Bar coating

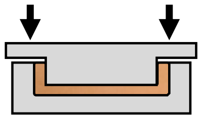


Processing / Shaping

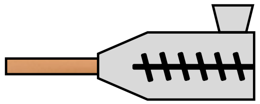
Tube making



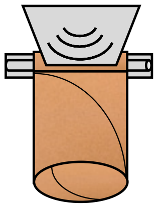
Hot pressing



Extrusion



Sealing and converting



Results

These prototypes replace:

XPS trays

PE / PET / aluminium tennis can

PE/PET tubes

Loïc VOISIN
Research Engineer (2025-2026)
LGP2 (A. Denneulin)
LEGI (F. Ayela)

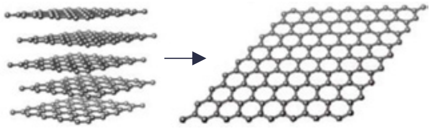
Green Graphene: Development and industrialization of graphene dispersion processes in various matrices and optimization of its production by microfluidic cavitation

Développement et industrialisation de procédés de dispersion du graphène dans diverses matrices et optimisation de sa production par cavitation micro-fluidique

FunPrint

Context

LEGI : Patented microfluidic on a chip exfoliation process producing high-quality graphene nano-sheets



- Graphene nanoplatelets suspension
  - Thickness <5 nm
  - Lateral size 150-250 nm
  - Concentration 1 to 5 g/L

LGP2 : expertise in complex fluid formulation, nanomaterial dispersion in liquids & polymers, bio-based materials (e.g., nanocellulose)

- Need to develop processes for dispersing graphene in various aqueous, solvent or nanocellulose matrices

Funded by / In collaboration with: UGA Université Grenoble Alpes; Linksium technology transfer & startup building Grenoble Alpes; LEGI Laboratoire des Ecoulements Géophysiques et Industriels; MADCAP NANO

Objectives

- Mastering the **exfoliation process** and modification of pilot line to increase production and productivity
- Production of **more concentrated solutions** using various chemical or physical techniques (20 to 50 g/L)
- To the **formulation of graphene-enriched complex fluid** (aqueous, solvent-based, deposits, Epoxy) in large quantities and at competitive prices

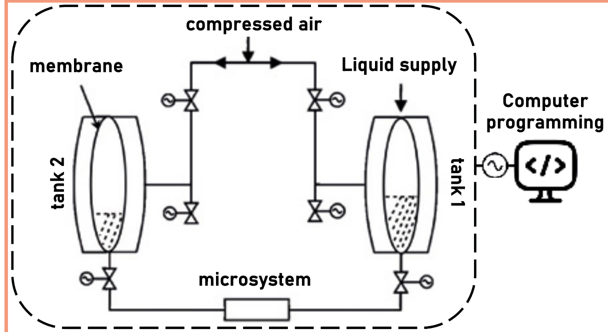
Working with the start-up:

MADCAP NANO
Microfluidic Advanced Cavitation Processes

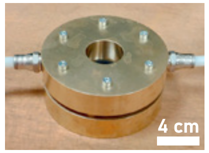
Applications:

- Conductive inks for printed electronics
- Additives for anti-corrosion, lubricant coatings or anti-abrasion surface treatment
- **alternative to the PFAS**

Methods



Complete flow loop with solenoid valves to achieve cost-effective & eco-friendly exfoliation of graphite by microfluidic cavitation [1]

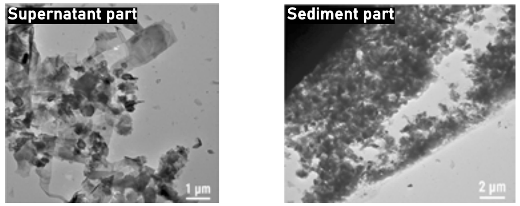


Microsystem

Centrifuge

SpeedMixer

Characterization:
UV Vis, TGA, SEM, AFM, TEM



TEM snapshots of centrifuged graphenofluid [2]

[1] X. Qiu, 'Procédé d'exfoliation du graphite en phase liquide dans des laboratoires sur puce', phdthesis, Université Grenoble Alpes, 2018. / [2] S. Ponomareva and F. Ayela, 'Anticorrosion and lubricating properties of an aqueous graphene-based nanofluid', Appl. Phys. A, vol. 129, no. 1, p. 18, Dec. 2022

Lorette BRAULT
Post-doc (2024-2027)
LGP2 (N. Marlin, G. Mortha)
Cermav (L. Heux,
S. Molina-Boisseau)

Valorization of the fibrous rejects from paper and cardboards recycling process

Valorisation des déchets fibreux issus de la filière de recyclage papier-cartons

BioChip

Context

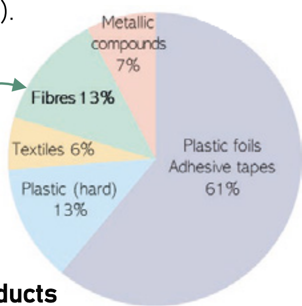
Paper and cardboards (PC) recycling process[1]

- 4.9 Mt of recovered PC in France/year, including

4 Mt for packaging sector (2020).
↳93% recycled into PC
Among the 7% waste:

13% of fibrous rejects

= 36 kt of non-valorized fibres per year in France.



Lignocellulosic high value products

- EU directives (Green Deal) on reducing consumption and replacing of petroleum-based products.
- High demand of cellulose and lignocellulosic compounds for ubiquitous applications.

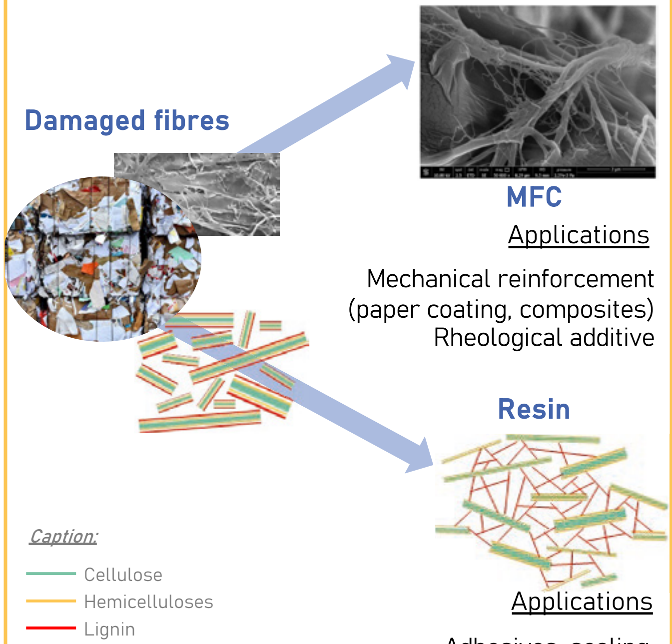
= high demand of virgin fibers and pure bio-compounds representing high energy and chemical consumption.

However, for some applications, non-pure and damaged cellulose from paper recycling process could be used.

Funded by:
anr agence nationale de la recherche
FRANCE 2030 PROGRAMME DE RECHERCHE RECYCLAGE
RECYCLAGE RECYCLABILITÉ RÉUTILISATION MATIÈRE PEPR

Objectives

Development of valorization methods tailored to the fiber quality and contaminant nature



Applications

Mechanical reinforcement (paper coating, composites)
Rheological additive

Applications

Adhesives, sealing, coating, composites,...

Methods

Characterization of rejects
Chemical: %cellulose, %hemicelluloses, %lignin, %stickies,... functional groups analysis (COOH, CHO, phenol,...)
Physical: Fibres morphologies and specific areas.

MFC production[2]

Rejects or model compounds → Purification → Mechanical fibrillation

Resin production

Rejects or model compounds → Chemical depolymerization → Fractionation/Purification → Stickies elimination or dispersion / Cellulose and hemicellulose carbonylation / Lignin amination → Cross-linking via drying

Characterization of MFC and resin
Mechanical, thermical, chemical and optical characterizations.

[1] K. Guiltaux, et al., ADEME 2023. Perspectives d'évolution de la filière papiers-cartons en France. 79 pages
[2] L. Dollié, Thèse Université Grenoble Alpes, 2019

Mahak FAZAL

Post Doc(2024-2025)
LGP2 (N. Belgacem, A. Denneulin, A.Blayo)
Tarkett (M. Koczorowski / A. Brogly / C. Maertens)

In-depth understanding of the interactions between film, primer, and ink for an industrial application: interfacial mechanisms between the different layers

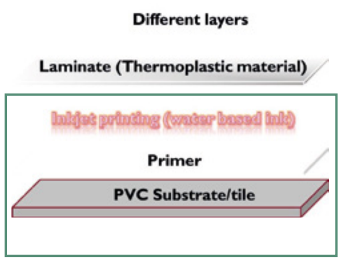
Compréhension approfondie des interactions entre film, primaire et encre dans le cadre d'une application industrielle : mécanismes interfaciaux entre les différentes couches.

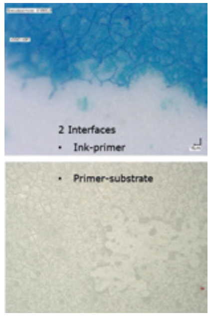
MatBio FunPrint

Context / Objectives

The multilayer configuration of inkjet-printed tiles for floor application comprises several interfaces. Each layers and interfaces need to be thourougthly characterised to allow a better understanding of the physical and chemical phenomenon involved.

For the current project, the objective is to better understand the system of PVC substrate, primer and water-based ink





Funded by: Tarkett

Methods

Characterisation of the primer formulated and provided by TARKETT

Techniques proposed in view of literature:

- For composition and structure: FTIR, NMR, GC-MS
- For adhesion: Cross-hatch tape test
- For rheological properties: viscosity, shear rate (using a rheometer)
- Surface properties: (surface energy/ surface tension) contact angle measurement
- Optical 3D measurement system for surface characterization (Alicona)
- SEM, AFM

Results

- The viscosity of the primer is decreased by adding the binder
- The morphology of the coated primer changes over time
- The roughness of the coated PVC sample is more than the uncoated sample (see fig 1).
- Roughness also visible at high resolution with AFM imaging

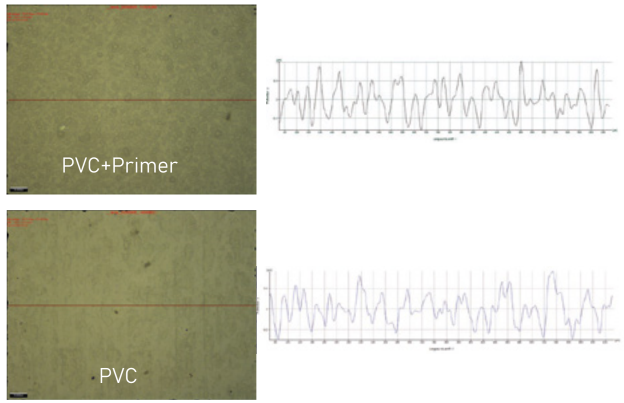


Fig 1: comparison of PVC and primer coated PVC using ALICONA at 20x magnification

Emilien FREVILLE
Post-doc / Research engineer
(2024-2026)

Injection-molding of cellulose based material for packaging applications

Injection-moulage de matières cellulosiques pour des applications d'emballage

MatBio

Context / Objectives

Alternative solutions to plastic packaging

SUPD
Single Use Plastics Directive (2019)

→ Progressive ban of SUP

PPWR
Packaging and Packaging Waste Regulation (2024)

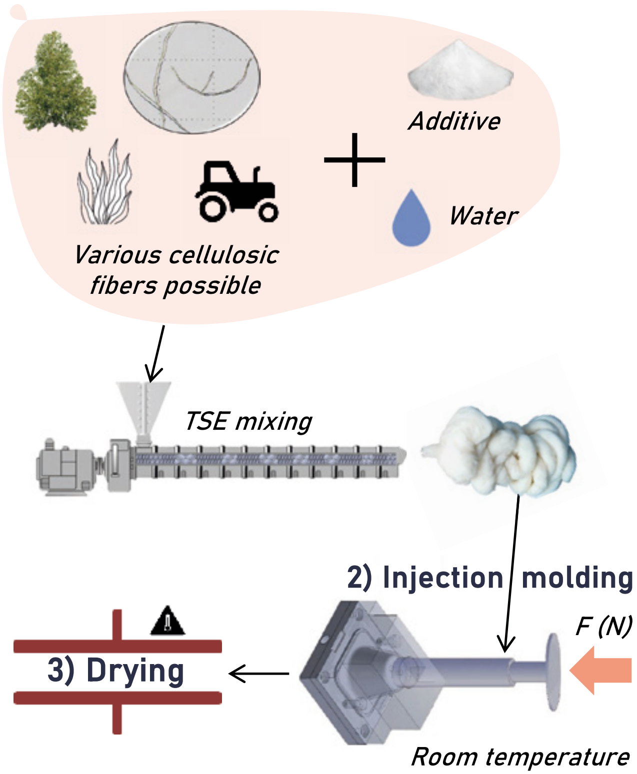
→ All packaging must be recyclable by 2030

→ End of SUP by 2040

AGEC
Loi anti-gaspillage pour une économie circulaire (2020)

Methods

1) Injectable cellulosic paste production by twin-screw extrusion



Results

Injection-molding of 3D objects containing at least 90% of cellulosic fibers

Svetlana PETLITCKAIA
Post-doc (2024-2025)
LGP2 (J. Viguie; J. Bras)

Reduction of the environmental footprint of high-value-added paper

Réduction de l'empreinte environnementale d'un papier haute valeur ajoutée

MatBio

Context / Objectives

Papermaking of non-wood plant fibers

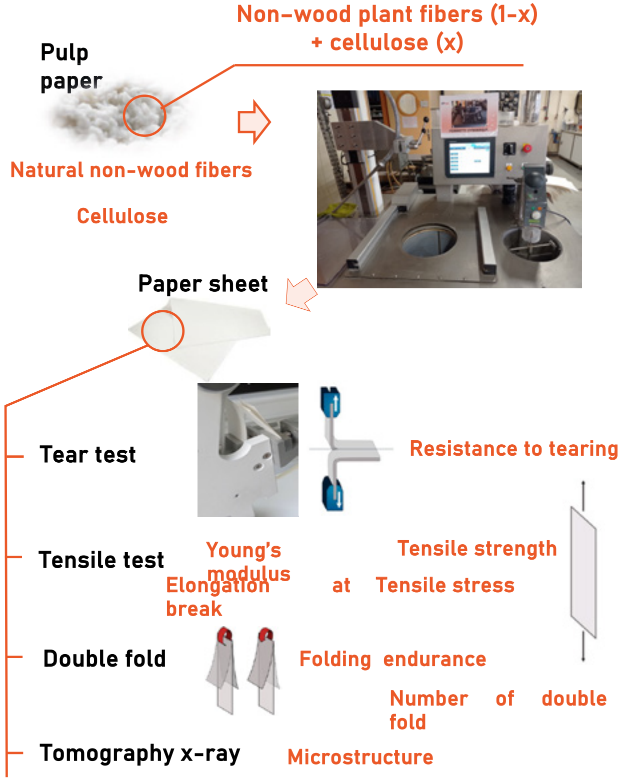
- Non-wood plants as sources of cellulose for paper

- Using of unrefined non-wood plant fibers

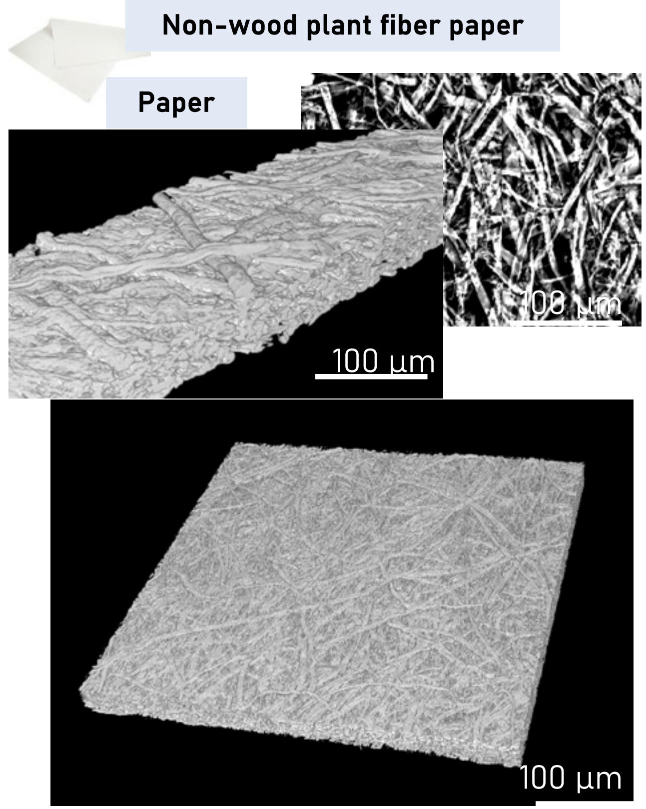
- Improuvement of the mechanical properties of paper based on natural fibers

Methods

Dynamic sheet former/ Paper characterization



Results



Emma PIGNERES
Post-doc (2025-2026)
LGP2 (J. Bras; N. Belgacem; C. Sillard)

Innovative Packaging and edible coatings to guarantee post-harvest Durability of Mediterranean fruits and vegetables production

Emballages innovants et enrobages comestibles pour garantir la durabilité post-récolte de la production de fruits et légumes méditerranéens

MatBio

Context

- **30-60% of fruits and vegetables are wasted** every year[1].
- European legislation is evolving towards **ban of single-use plastics**[2].
- **Edible coatings** are growing as plastic packaging alternatives to enhance fruits and vegetables quality[3].
- This research is part of PRIMA project **DurInnPack**, regrouping eight partners from the Mediterranean basin.

References
[1] FAO (2015). Global Initiative on Food Loss and Waste Reduction.

[2] Regulation (EU) 2025/40

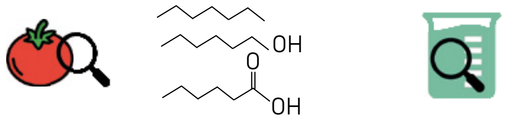
[3] Martins, V. F. R. et al. (2024). Recent Highlights in Sustainable Bio-Based Edible Films and Coatings for Fruit and Vegetable Applications. Foods, 13(2). https://doi.org/10.3390/foods13020318

Funded by: anr agence nationale de la recherche, PRIMA

Objectives

- Understand **the surface and adhesion properties** between the edible coating and the fruit.

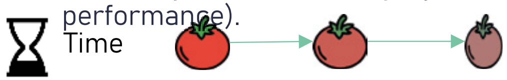
- Understand the **parameters impacting** these properties.



Composition, Morphology…

Viscosity, Surface tension, Drying…

- Assess the **evolution** of the fruit surface and edible coating properties **over shelf-life** and its impact on the **coating durability** (adhesion, integrity, performance).



Time

T°C

RH

Change in **fruit** composition, texture, surface energy

Change in **edible coating** mechanical properties

Methods

1 Fruits with different surface properties

Characterization over time
- Surface structure/morphology
- Surface composition
- Surface free energy

2 Edible coating → Biopolymers from waste sources

MATRIX
Cellulose + CNF
Chitosan + CNF

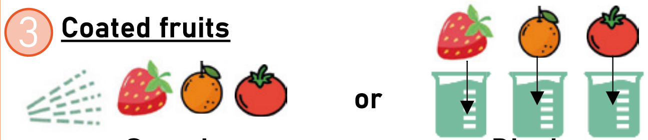
\+

FUNCTIONAL ADDITIVES
Essential oils and phenolic compounds

Characterization
- Viscosity
- Composition
- Surface tension

Characterization over time
- Thermal properties
- Mechanical properties
- Barrier properties

3 Coated fruits



Spraying or **Dipping**

Characterization over time
- Coating adhesion
- Film forming properties
- Durability of the coating

Candice REY

Research Engineer (2023-2026)
Cellulose Valley – LGP2
(director: Julien Bras)

Short term innovation team project coordinator in *Cellulose Valley* for new cellulose based high performance recyclable packaging

Coordinatrice projets à la Cellulose Valley pour l'équipe d'innovations court-terme pour des nouveaux emballages cellulosiques, performants et recyclables.

MatBio

Context / Objectives

A story of Single-use plastics regulations to limit global warming:

- 2018: SUP (Single Use Plastics) directive for European countries.
- 2019: AGEC (Anti-Gaspillage pour une Economie Circulaire) law in France.
- 2024: PPWR (Packaging and Packaging Waste Regulation) for European countries.

Need for sustainable packaging solutions:

- Cellulose is a 1rst choice candidate to design bio-based packaging.
- Biodegradable, recyclable in paper/carboard stream, naturally present on earth.

Need improvement to meet packaging requirements

Cellulose Valley

Cellulose Valley chair: Innovation to serve society expectations.

Aptar, Ahlstrom, CHANEL, CITEO, Fondation Grenoble INP, DECATHLON, DS Smith, GUILLIN, Marie, Grenoble INP UGA, Pagora

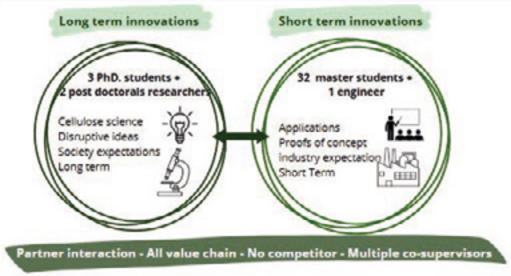
Methods

Long-Term innovations team:

- 3 PhD students.
- 2 study engineers.

Short-term innovation team:

- **32 Proofs of concept** to design bio-based packaging, resistant, biodegradable and recyclable.



Scientific communications:

- Webinaire (CELLIENCE), 500 suscriptions.
- Disseminations in special events and congresses.

Results

Mid-term Chair report:

- Discover and understand all our applications and concerns in our mid-term report.

- Since 2022: 23 innovative bio-based packagings development.

Laboratoire de Génie des Procédés pour la Bioraffinerie, les Matériaux Bio-sourcés et l'Impression Fonctionnelle

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