CELLULOSE VALLEY CHAIR Mid term report

Cellulose Valley

GRENOBLE







BY FONDATION GRENOBLE INP







NOTE FROM THE CHAIR HOLDER
NOTE FROM THE DIRECTOR OF THE FOUNDATION GRENOBLE INP
NOTE FROM THE STEERING COMMITTEE PRESIDENT
NOTE FROM THE PRESIDENT OF THE SCIENTIFIC COUNCIL
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Note from THE CHAIR HOLDER

There's no longer any doubt that our society needs new packaging solutions to avoid pollution and reduce environmental impact. Cellulose science has come a long way since I took my first steps in the field 20 years ago. It is therefore one of the solutions for moving forward with developing high-performance materials derived from nature that are both recyclable and biodegradable. This challenge prompted me to launch this Chair of Excellence with 8 major industrial partners."

Julien Bras

Professor at Grenoble INP PAGORA, and chair Cellulose Valley holder.

Mate from THE DIRECTOR OF THE FOUNDATION GRENOBLE INP

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"The Grenoble INP Foundation is proud to be able to support the Cellulose Valley Chair in its complex scientific challenges and its critical environmental impact on the future of our society. The presence of numerous partners representing the entire value chain from the upstream plastics/paper/cardboard industry, as well as downstream industrial users, also demonstrates the growing interest in the work carried out by the research teams. Our support for this Chair of Industrial Excellence is therefore a long-term commitment, spanning several years."

> Benait Giroud Director of the Foundation Grenoble INP

Note from THE STEERING COMMITTEE PRESIDENT

Cellulose is the most abundant organic molecule on earth, and its potential is still far from being fully explored, developed and utilized. The aim of the Chair is to broaden its areas of application, particularly in packaging, with new solutions that replace other, less environmentally-friendly materials with the same or better levels of performance. I look forward to benefiting from the Chair's scientific power, its laboratory resources at LGP2 and its network of partners at different levels of the value chain, to bring virtuous solutions to market."

Vincent Renaudie

Steering committee president and R&D director at DS SMITH packaging group.

The PRESIDENT OF THE SCIENTIFIC COUNCIL

Packaging materials play a crucial role in our society. We use them en masse, which raises major environmental concerns. Plastic and aluminum packaging solutions still dominate the market thanks to their high properties and good cost/performance ratio. However, materials containing plastics present environmental challenges such as recyclability issues, the accumulation of microplastics in our environment and a high carbon footprint. Cellulose, a natural, renewable, biodegradable and recyclable substance, offers a promising ecological alternative to traditional plastics. Of course, the technical challenges of replacing plastics are considerable. The adage "He who seeks, finds" takes on its full meaning here. Investing in the research and development of cellulose and other biomaterials suitable for the circular economy is essential. To succeed, collaboration between researchers and industrial partners is crucial to discovering innovative, environmentally-friendly solutions."

> President of the scientific council, Ahltrom R&D , manager group product and technology development.



Cellulose Valley PRESENTATION OF THE CHAIR



The Cellulose Valley Chair is an excellence industrial chair supported by the Fondation Grenoble INP. It was founded in November 2021 and started its activities in January 2022 with 5 industrial sponsors. Since its inception, the Cellulose Valley Chair has expanded to include 3 additional partners, bringing the total number of companies involved in the project to 8. The objective is to develop sustainable and recyclable highly performant cellulosic solutions for packaging.

The Chair is designed to meet societal expectations and anticipate the scientific and technical challenges posed by the necessary environmental transition in packaging. A popularizing science video has been developed to explain the current issues facing Cellulose Valley. The objectives and motivations of the projects are clearly explained, so that everyone

can understand what is at stake. An English version of this video is available since May 2023.



During 4 years, Cellulose Valley is supported by 8 industrial sponsors and works as an ecosystem evolving between research and industrialization.



8 INDUSTRIAL sporsors

FOR ALL THE CHAIR DURATION (2021-2026):

32 proofs of concept
3 thesis

 2 one year research project (post doc & study engineer)

> 1 research enginner



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PARTNERS MEMBERS

SAN STRANS

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INDUSTRIAL PARTNERS





Thierry Maucatel Innovation director

at LDC group

Marie and the LDC group are specialists in fresh, moist and health-sensitive products. To date, only plastic materials meet all the preservation constraints of our product ranges.



Christophe Peck Packaging R&D manager, LDC group

"As part of their packaging strategy, and in particular to reduce dependence on plastic materials. Marie and LDC have joined Cellulose Valley to undertake long-term research into cellulose materials, in which our products cannot currently be packaged.



Thierry Vallet R&D director at Marie, LDC group

We expect to identify the technological solutions that will improve the technical functionalities (water, grease and gas barrier) of 100% cellulose packaging materials.



Emma Camps Packaging engineer at LDC group





Nicolas Jissier VP group innovation, Ahlstrom



Charlène Reverdy R&D scientist. Ahlstrom



Erkki Laiti Manager group product and technology development, Ahlstrom



Noël Cartier Head of Global Science and Technology Development

CHANEL



Pascale Marciniak Packaging Research and

Innovation director, Chanel



Virginie Recoura •

CSR packaging innovation manager, Chanel "The Cellulose Chair is an exceptional scientific initiative bringing together experts with a wide range of skills. As a representative of Chanel, I'm delighted to be contributing to this cutting-edge research into cellulose fibers, their transformation processes and the inherent barriers. This allows us to be at the heart of this research with enthusiastic partners."



LounaVial Materials engineer for Innovation Packaging, Chanel CITEO Donnons ensemble une nouvelle vie à nos produits.



Mélanie Eymas Research and material innovation manager



Florine Rollin Eco-design project manager





Vincent Renaudie Group R&D packaging solutions director



Rémy Botalla-

Gambetta Packaging solutions project leader Aptar 🖌



Christophe Marie Product sustainability director





Patrice Leone Material & science director

Our expectations are to acquire scientific knowledge in the field of cellulose in order to offer our customers new, more sustainable solutions. Setting up collaborations with members of the Cellulose Chair Although there are still 2 years to go, we already consider the experiment to be conclusive.



Randy Mujica R&D engineer





Margot Plée R&D food packaging engineer



Franck Bournaud Division director at Groupe Guillin



Vrignaud

manager

Research & innovation

Julie Wutrich Laboratory project manager

DECATHLON



Julien Lambert

Packaging innovation leader, Decathlon "At Decathlon, our ambition is to eliminate all single-use plastics by favoring paper materials with a very high recyclability rate. Current materials don't always meet the latter expectation, so we needed a group of technical experts to help us invent them.



Florent Maisch Component and technology engineer, Decathlon



RESEARCHERS INVOLVED IN THE CHAIR







Osabelle Deslages Associate professor, Grenoble INP PAGORA



Quentin Charlier

Associate professor, Grenoble INP PAGORA



Céline Martin Associate professor, Grenoble INP PAGORA

Jérémie

Vianié

LGP2

Research engineer,



Mahamed Naceur Belgacem Professor, Grenoble INP PAGORA



Stéphane Dufreney ^{Engineer assistant,} LGP2



Alain Dufresne Professor, Grenoble INP PAGORA



Maxime Jerrien ^{Study engineer,} CNRS



Evelyne Mauret Professor and PAGORA school director



Cécile Sillard ^{Study} engineer, LGP2



Anne Blaye Directress of LGP2 Laboratory

(corporate relations)



Gaëlle Calvary Professor Grenoble INP ENSIMAG & Innovation and Company Vice-president





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The Chair Cellulose Valley A KEY ACTOR IN THE ENVIRONMENTAL TRANSITION



Currently, plastic is one of the most widely used materials in the world. It is found in many everyday products, from food packaging to electronics, clothing, and sports equipment. Unfortunately, this widespread use of plastic has a significant impact on the environment. When they are not all well managed, plastic waste may pollutes oceans, rivers and soils, threatening wildlife, and plants. In particular, micro plastics, mainly resulting from the fragmentation of plastic, represent a danger for the environment and human health. In addition, the lack of fossil resources, the need to reduce carbon emissions and the accumulation of plastic waste are the main problematics that push the world today to find solutions to reduce the use of petroleum-based plastics. Plastic have fantastic properties for packaging regarding processing, inertness, food contact transparency or barriers to liquid and gas. They have been extremely useful in our society to limit food waste among other advantages. However the pervasiveness of plastic packaging and its impact on the environment have ignited a global movement towards sustainable alternatives. This shift is particularly evident in the packaging industry.

It is estimated that between 25 and 30 million tons of plastic enter the oceans annually. This alarming trend has spurred the development of numerous laws and regulations aimed at curbing plastic packaging use and promoting environmentally friendly alternatives. Legislative bodies worldwide are implementing measures to reduce plastic waste and promote sustainable practices. For instance, a comprehensive waste reduction strategy has been outlined, encompassing the phasing out of single-use plastics, enhanced consumer information, waste generation mitigation,

and reuse promotion. The specific laws and regulations enacted to achieve these objectives are detailed in subsequent sections.



Some numbers TO KEEP IN MIND

Global plastic waste production by type (in millions of tons*)





In the space of two decades, the annual production of plastic waste worldwide has almost doubled, according to OECD data. Plastic waste is expected to almost triple worldwide by 2060: half of all plastic waste will still be landfilled, and less than a fifth will be recycled, according to the report.



MORE THAN 78 MILLION TONS OF PLASTIC WASTE GENERATED IN 2018

Sources: www.nationalgeographic.fr/le-plastique-en-10-chiffres www.nationalgeographic.fr/environnement/91-des-dechets-plastiques-ne-sont-pas-recycles www.ellenmacarthurfoundation.org

In recent years, awareness of the scale and dangers of plastic pollution has paved the way for greater political intervention. As Euronews reported last year, more than 100 countries already ban single-use plastic bags in full or in part, and many are also banning other disposable items made from the material (*cutlery, straws, etc.*).

Reducing and recycling is a priority in the fight against plastic pollution. According to an Ipsos survey of over 24,000 people, 85% of respondents in 32 countries worldwide agree that there should be international standards banning single-use plastics.

70,5%

still places Europe well ahead of the rest of the world, with an average **GLOBAL RECYCLING RATE OF 59,9%** in 2021.

CELLULOSE

appears to be a promising solution thanks to its numerous advantages: Most abundant polymer on planet earth Biodegradability Renewability Recyclability

To further increase how much and how efficiently we recycle, the value chain actively works on achieving several 'qualitative targets' outlined in the new EPRC report. These include guidance documents on how to implement separate collection of Paper for Recycling which would be the best way to improve recycling, ecodesign projects to enhance paper products' recyclability, and educational campaigns for the public.

The creation of the chair Cellulose Valley is part of this environmental context.

Source: www.cepi.org/press-release-the-paper-value-chain-reached-a=705-recycling-rate-in-2022

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A path FOR A SUSTAINABLE WORLD

In order to provide more environmentally-friendly alternatives, the various collaborations with our industrial partners will enable us to propose new solutions for high-performance packaging that meets the following criteria:

- > Made from bio-sourced origin, mostly cellulosic (at least 80%)
- > Preferably recyclable
- > If not, biodegradable
- > Guaranteeing mechanical resistance required for the application
- > Providing barrier performances needed as a packaging.

This work will enable us to meet the numerous commitments made by end-user companies, who are announcing the use of 100% recyclable, reusable or biodegradable packaging by 2025 or 2030.

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SOME NUMBER FROM 2021 TO NOW:



1 RESEARCH ENGINEER





DOCTORAL

RESEARCHER

POST



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Research ROADMAP OF THE CHAIR

The Chair is also dedicated to increasing and consolidating the excellence of partner companies and Grenoble INP by organizing a structuring activity of reflection and research on an international scale around the theme of cellulose materials in the packaging field.



EDUCATION ACTIONS

To meet societal and political expectations and the commitments of the sector's manufacturers over the next few years, it is important to move quickly and have a sustained annual rate of results acquisition, as well as a longer timeframe for the development of innovative breakthrough solutions.

This is why the chair will simultaneously offers:





BREAKTHROUGH RESEARCH IN THE FIELD OF CELLULOSE.

[A SHORT TERM INNOVATION TEAM:]



MASTER'S DEGREE LEVEL RESEARCHERS PER YEAR DEDICATED TO PROOFS OF CONCEPT

RESEARCH ENGINEER TO COORDINATE RESEARCH AND INDUSTRY The Chair is structured around these two levels of research, with a common research point: CELLULOSE IN ALL ITS STATE.

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Partners relationship AND DISCUSSIONS

Each year several scientific exchange meeting are organized. These meetings provide an opportunity to exchange scientific viewpoints and problems encountered on the industrial side, so as to better orientate the lines of investigation for each project. These 3 meetings also enable us to better understand the expectations of each partner and of our company.

More specific meeting for each Proof of Concept is organized regularly between the students on placement and the industrial partners involved in each project (the sponsor) to share results and progress. Visit of partners facilities have also been organized.











Steering committee Ahlstrom

Moreover, twice a year, a steering committee is organized in one partner facility with more focus on their research roadmap and facilities. This event is important for internal communications and allows all the partner members to set up potential collaborations.





Steering committee Cited

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The Cellulose Valley team ALONG THE YEARS

Since the creation of the chaire, the number of projects and persons involved increased. This marks the rise of interest in sustainable packaging and the needs of informations and proofs of concept in the aim of an industrial transition.







EDUCATION ACTIONS IN THE CHAIR

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COLLABORATION WITH GRENOBLE INP PAGORA STUDENTS

The Cellulose Valley Chair is hosted by the LGP2 laboratory and Grenoble INP -Pagora, UGA. This ensures a strong and privileged link between the Chair's research team and the students (*Engineers or masters*). It also makes it possible to set up joint education projects that benefit all parties.

The expected results of the education actions at the beginning of the chair are listed below:

 Joint projects between the Chair's research team and courses offered to students at Grenoble INP -Pagora, UGA.

 Enriching future engineers' expertise and understanding of cellulose.

 > Drafting of technological and economic reports on topics related to the use of cellulose in packaging.
 > Propose international webinar and student

challenges every year on cellulose

 Favor dissemination of science of cellulose at all level of education All these actions are discussed in details during scientific council every semester and summarized during Steering committees.

The Cellulose Valley prize was presented to first-year students at Grenoble INP Pagora in recognition of the best scientific projects and the second-year students for the best technological watch presentation. Mr. Julien Bras provided supervision for all technological watches. The most suitable solutions are shared with our partners at Cellulose Valley.



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STUDENTS DEMONSTRATOR PROJECT: REINVENTING VEGETABLE NETS

In 2023-2024, the chair has decided to support financially a demonstrator project called DEEP project. In this context, Grenoble INP - Pagora students have been involved in a several-month project linked to the chair Cellulose Valley.

AIM OF THE PROJECT

Design a prototype of bio-based vegetable net answering to these requests:



> bio-based, involving a minimum of 80% of cellulose
 > recyclable

allowing vegetables view
 supporting 2kg of vegetable
 resistant to humid conditions

This project has resulted in the examination of a number of papers and potential avenues for enhancing the packaging's extensibility on one hand and enabling the visualization of the inner product on the other. The team conducted a

comparative analysis of the paper structure and humid resistance of four different papers. Based on this analysis, they designed slots with varying geometries and spaces to enable the stretchability of the packaging. A prototype of the packaging has been constructed, capable of supporting 1.5 kg of fruit or vegetables. It is entirely made from slotted paper and starch glue, as illustrated in the figure below.

ALTERNATIVE TO PLASTIC NETS FOR FRUITS AND VEGETABLES



Introduction

Worldwide plastic production continues to rise, reaching over 400 million tonnes in 2019. The result is the generation of 7 billion tonnes of plastic wate since 2015, half of which comes from plastic packaging and only 9% of which is necycled. In France, 68% of plastic packaging is used in the food sector, making it one of the most polluting sectors with the plastics industry. This is the reason why the aim of this project is to design an alternative to the plastic netting used in the apri-bod sector.



STIMULATING CREATIVITY AND INNOVATION: CELLENGE CONTEST

The cellulose Valley launched a student contest CELLENGE in November 2023, for the first time. This competition aims to design a rigid cellulosic packaging to replace primary packaging, as a solution to the European directive against single-use plastics (SUP). The award is 1000€ to be shared within the team member and the participation of the next steering committee.

This contest has been mixed with a teaching project from Grenoble INP Engineering School gathering more than 150 students. The title of the contest was the subject of an innovation project consisting of 25 hours of imagining a bio-sourced alternative to plastics daily products. The chair members have done videos, organized visits of the chair and spend time in classroom with students to give more details about Cellulose.





Actually 3 student teams from the teaching projects and one other team subscribed to the contest, the jury is composed of Julien Bras, chair

director, Vincent Renaudie steering committee president, Erkki Laiti, scientific council president, and Candice Rey, research engineer in charge of the project.

The first prize of the jury is project called YOLOSE and presents an innovative process to produce 3D cellulosic packaging. This project was supported by Daniella SEMAAN, an engineering student at Grenoble INP PAGORA, and supervised by Emilien Freville, PhDs student at LGP2. She had the opportunity to present her innovation at the steering committee of the chair in July 2024, at CITEO.

A second jury's favorite prize was awarded to a group of 4 students from Grenoble INP PHELMA. They imagined a new design for refillable tooth past tube in order to manufacture it from cellulosic material and to reduce product waste.







LEARNING WHILE HAVING FUN: CELLULOSE VALLEY - THE GAME

The serious game of the chair has been designed and tested this year with the POC students. The game will be deployed this year towards the partners of the chair. A video has been done and validated by the steering committee member in order to communicate on the serious game.

[THE SERIOUS GAME IS COMPOSED OF]



8 DEBATE CARDS TO RESTORE KNOWLEDGE

John Francis Kenwright



Serious game project involves 60 cards divided in two part of game: 1 part of quiz, 1 part of debate. PerForm which is the innovation plateform for the teaching tools of Grenoble INP helped the chair members to build this project through a collaboration with John Francis Kenwright, English and educational innovation teacher, and SMART GAMES manager in Grenoble INP PAGORA. The challenges involved in the quiz phase and the debates proposed have been invented by the Chair member, as for the scenario and game play rules. One promotion video and one tutorial video are currently recorded to help the setting of the game. The promotion video has been validated by the steering committee.



It is possible to flash this QR code to watch the video.









Visit to ATHANOR sorting center



The chair also organized a visit in a sorting center with all the short term and long term team member in order to give the opportunity to know better about recyclability. Julien Bras, chair Holder, presented the chair and the challenges in the use of cellulose to produce packaging to highschools student at the occasion of the "fête de la science" in the LGP2 laboratory. This was the occasion to give some informations about cellulose, barrier paper and carboard, and the importance of designing recyclable packaging.





COMMUNICATION TOWARD SOCIETY



POPULARIZING ABOUT CELLULOSE AND ITS APPLICATIONS

20% of the time of the chair is dedicated to diffusing and exchange knowledge about cellulose as a raw material and its requirements to be used in packaging. Several actions has been done in this goal under different layout like, radio interview, webinar, conferences.

The chair members participate to some event in order to popularize cellulose and its advantages as being used in the packaging field of application.

The chair members participate to the *Tech&Fest event*. An exhibition mixing technology about every scientific field. The chair had a booth and presented some proof of concept. The CELLENGE contest was also introduced to some students. This event was organized for 3 days and a wide public type had the opportunity to attend. The chair members were present and could share discussions with students, families, academic and industry representatives.



Tech&Fest

The chair was also present in the french event *Mondial des métiers* sharing a booth with Paper and Carboard Careers. It has been the occasion to present to schoolchildren and young student the wide applications of bio-based polymer.

In may 2023 Julia Pescheux Sergienko, PhD student 2nd year and Julien Bras the chair holder attended to the French edition of an international event named *Pint of Science*. Scientific talks are organized the same day in 54 cities of France, mostly in bars, in order to popularize science. They gave a talk about cellulose and the chair Cellulose Valley.





SUMMARY OF THE ACTIONS OF EXTERNAL COMMUNICATIONS DONE BY THE CHAIR MEMBERS DURING THE LAST YEAR.

DATE	MEMBERS NAME	EVENT NAME	EVENT TYPE
18-22 September 2023	Julien, René	European Polysaccharide network of excellence conference	Conference
12 October 2023	Julien, Candice	Fête de la science	Society Dissemination
19-20 October 2023	Julien	International conference packaging (Slovenia)	Conference
8 November 2023	Julien	Visite lyceen Argouge	Society Dissemination
December 2023	Candice	« Mondial des métiers »	Exhibition Society Dissemination
11 January 2024	Julien	Conference academie des sciences Paris	Conference
February 2024	Julien, Julia, Mathilde, René, Candice	Tech&Fest	Exhibition
6 th of February 2024	Julien, Candice	Kaleidoscope Week, Grenoble INP	Society Dissemination
10 February 2024	Julien	Journée portes ouvertes de Grenoble INP	Society Dissemination
September 2023 to May 2024	Julien, René, Mathilde, Candice	Innovation project - Grenoble INP	Student challenge CELLENGE
9-12 April 2024	Julien	Pulp & Beyond (Finland)	Conference
22-26 April 2024	Julien	FB POL (Brazil)	Conference
May 2024	Julien	Polynat day	Conference
April 2024	Julien, Mathilde, René, Candice	LGP2 visit with the students of the innovation project - Grenoble INP	CELLENGE
June 2024	René, Candice	IAPRI (Spain)	Conference
June 2024	Julien	Seminar North Carolina State University	Conference
June 2024	Julien	Tappi Nano	Conference

PRESS AND RADIO COMMUNICATIONS

To touch another type of public, the chair members participated to several interviews for specialized and non-specialized newspapers (as well as two published articles). In addition, interviews on radio stations such as NRJ and RCF (15-minute programs) helped to publicize the Chair's themes.

A press release was also issued on January 6, 2022 to present the Chair, its objectives and the issues at stake in today's society. This press release is available on the Cellulose Valley website.

An article was also written in the French newspaper Emballage Magazine about Julien Bras and the Cellulose Valley in October 2022.

An article in the French newspaper Le Dauphiné has been written to present the chair, its challenges, and the importance of sustainability in the packaging application in January 2024.





Ici on agit ! Environnement

Accompagné de l'INP de Gre-

Mercredi 17 janvier 2024

Grenoble

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La chaire Cellulose Valley veut révolutionner l'emballage

Lancée en 2022 et portée par la Fondation Grenoble INP, la chaire descellence industrielle Cellulose Valley cherche à diffuser et acquérir du savoir sur la cellulose. Remplacer les emballages plastiques par des emballages entièrement recyclables, biosources et biodégradables, c'est le rève de **Féquipe interdisciplinaire** dirigée par Julien Bras au sein du laboratoire LGP2 et de Grenoble INP Pagora.

a cellulose est la molécule organique la plus présente sur la Terre, composant la paroi cellulaire de nombreux végétaux. Quand on en parle dans le domaine de l'emballage, c'est souvent pour désigner des produits tels que le papier, certains cartons, les boites d'œufs, etc. Au cœur du campus de Grenoble, une équipe interdisciplinaire s'intéresse à cette matière, « la seule à norropir proposer de nouveaux objets biodégradables, plastique par exemple biosources et recyclables ». Julien Bras travaille dans ce noble et de plusieurs industridomaine depuis plus de 20 ans. La cellulose est une matière qui pourrait en remplacer beaucoup d'autres, mais il reste énormément de choses à découvrir dessus », explique-t-il. Car si elle possède de nombreux avantages, elle est aussi très hydrophile, poreuse, non transparente et peu résistante à la chaleur. Avec ces quatre « défis à relever », difficile de la mise en forme »



La chaire d'excellence Cellulose Valley lie recherche et enseignement pour développer les emballages en cellulose recyclable et biodégradable. Photo Le DL/Valentin Offer

d'imaginer la cellulose - « tout Et celles-ci interagissent enen conservant ses propriétés tre elles et ne sont pas déliées intéressantes » - remplacer le les unes des autres.

Comment améliorer **Femballage** cellulose

els de taille (Chanel, Decathlon Julia Pescheux-Sergienkon, ou Citeo). Julien Bras décide de en thèse, travaille sur la partie criter en 2022 - pour une durie chimie. Sa mission : « Réfléde quatre ans - la chaire Celluchir à comment apporter de la lose Valley pour travailler sur barrière à la cellulose - Il faut le temps long à améliorer les donc étudier la molécule en lui propriétés et les fonctions de la apportant des nouvelles fonccellulose. « Concrètement, intions sans non plus la dénatudique-t-il, cela se fait de trois per, « pour ne pas créer un noufaçons : l'approche chimique, veau plastique », explique l'approche du matériau et celle Julia. Grice à des nanoparticu-

les, la cellulose peut devenir

plus dense et imperméable aux gaz par exemple. Sur ce qui concerne le déve-

> loppement des matériaux en cellulose, René Romero explore leurs côtés actifs. « L'idée c'est de voir comment un emballage fonctionne sur la durée de vie du produit », expose-t-il. Son travail est ainsi de développer de nouvelles structu-

res, applicables dans le domaine de l'agroalimentaire, de la cosmétique et de l'électroni-014 Mathilde Bernard-Catinat,

dernière arrivée dans la chaire.

3D des emballages. Elle est en quelque sorte aux frontières de ce que font Julia et René. - Ce que l'on fait avec du papier doit s'adapter à certains types de produits. C'est le cas de barquettes, de pots de yaourts ou de gobelets -, raconte la doctorante. Celle-ci travaille en particulier sur la cellulose moulée qui constitue entre autres les boltes d'orufs.

La science de la cellulose est en pleine révolution -

Si on insiste sur la recyclabili té de la cellulose, les cher cheurs insistent surtout sur le fait qu'elle soit tout simplement recyclée, « En France, la chalne de tri du papier et du carton est maltrisée à hauteur de 80 %. On a cet avantage de profiter d'un système déjà en place -, indique Julia. Niveau Metalation aussi, les directives européennes et françaises

contre le gaspillage et les emballages plastiques fusent. - Il y a beaucoup d'alternati ves à l'usage du plastique, et nos recherches en font partie -, relate Mathilde. Julien Eras, qui a commencé à étudier la cellulose en 2001, est très heureux de voir ce sujet mis au-devant de la scène, mé me par des acteurs non universitaires. « Depuis 2008, on déconvre des choses tous les jours. La science de la cellulose

est en pleine révolution ». achève le professeur. s'occupe de la mise en forme • Valentin Office

SCIENCE SHARE WITH SOCIETY

CELLIENCE webinar: diffusing the knowledge about cellulose wide world

Since the creation of the chair Cellulose Valley, a webinar called CELLIENCE is organized by the chair members. The first edition was in December 2022 and almost 300 people from all around the world subscribed to the event. Well-known researchers were invited to give a talk about cellulose, from characterization to application. This remote event brought together around 150 people connected at the same, with a common taste for knowing more about cellulose.

The 2nd edition of our webinar CELLIENCE was held on December 12th, 2023, enabling participants to interact with international speakers. The day was organized around three major cellulose-related themes, with over 480 registrants, and 250 participants connected in the time.

The chair will organize the 3rd edition of CELLIENCE in December 2024, and expect to see numerous registrations!

CELLENCE

Cellulose Science Webinar 2023





Part I : Flexible Cellulose materials

- gog lo g.30 a.m : Overview of paper physics and link with packaging - Pr Artem Koulachenko, KTH, Sweden
 g.30 lo g.55 a.m : Coaling solutions for paper based materials
- Pr Wolfgang Bauer, TU Graz, Austria
- . 9:55 to 10:20 a.m : Innovative nanocellulose films
- Vinay Kumar, VTT, Finland

Part II : Rigid Cellulose materials

status to souge am: Criticiose use in composites
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 surface-madited CNDs in composites
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 Tarek, Jaharen, Involted, Canada

Part III: Other cellulose applications

- + 11:35 to 12:00 a.m : Solubilization and regeneration of cellulose for textile fibers
- Pr Herbert Sixta (tbc): Aalto, Finland
- 12:00 to 12:25 p.m : Rheology of Cellulose suspension
- Pr M. Bortner, Virginia Tec, USA
- 32:25 to 32:50 p.m : Hybrid Cellulose Nonomoleriols
 Pr. Valdeir Arantec, USP, Brazil



THE CHAIR IS PRESENT IN CONFERENCE

Cellulose Valley members are presents at international and national conferences, with participation in the following congresses among others:

> FinnCeres, Finland - May 2022
> Nanocellulose day, Norway - October 2023
> ACS Cellulose division, USA - March 2023
> Tappi Nano, Canada - June 2023
> EPNOE, Austria - September 2023
> Carnot Polynat day, Grenoble - May 2023
> Pulp&Beyond, Finland - Avril 2024
> FB POL, Brazil - June 2024
> Tappi Nano, USA - June 2024
> IAPRI, Spain - June 2024





THE CELLULOSE VALLEY IN THE ACADEMIE DES SCIENCES

A highlight of the year 2023 was the chair Cellulose Valley presentation at the Académie des Sciences. On October 17, Julien Bras was awarded the Arkema / Académie des Sciences Prize for Innovation in Chemistry for Sustainable Materials 2023. He had the opportunity to give a talk to present his research projects and took advantage of this moment to introduce the chair Cellulose Valley and the hosted projects.

This prestigious prize rewards his high-level work in chemistry, paving the way for innovative solutions for sustainable and responsible development. This research - which has given rise to 195 publications and 22 patents - is a perfect illustration of the prospects offered by the use of structures derived from the plant world, in particular cellulose at all its scales. By chemically modifying nanocelluloses to endow them with new properties, the researcher and his team are demonstrating that it is possible to replace fossilbased polymers in numerous applications ranging from packaging to composites.

A senior member of the Institut Universitaire de France, Julien Bras is a scientist who is convinced of the need for technology transfer of scientific activities, as demonstrated by his regular collaborations with industry, the creation in 2022 of the Cellulose Valley Chair of Industrial Excellence and his contribution to the emergence of several start-ups.



SCIENTIFIC PUBLICATIONS

Some members of the chair (Julien Bras, Julia Pescheux-Sergienko and Candice Rey) had the chance to join other researchers from the LGP2 laboratory to write a review article about tridimensional cellulosic material, published in October 2024. This is the first review summarizing the novel and common processes to design 3D cellulosic packaging.

Julia Pescheux Sergienko and René Rafael Romero Lezama had the chance to present scientific posters in conference in France and abroad.

> GdR DUMBIO in Grenoble (France), May 2022

Cellulose Valley: Reinventing Packaging. Engineering of new highly performant cellulose based materials. Tappi Nano in Helsinki (Finland), June 2022

Nano-cellulose based coating to obtain high performance sustainable packaging solutions

> ACS in Indianapolis (USA), March 2023

Development of new high-performance recyclable packaging within Cellulose Valley

> EPNOE conference (Austria), September 2023

Development of a multilayer cellulosic material based on cellulose foam and paper for water vapor barrier shift concept in packaging.

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Novel technologies for producing tridimensional cellulosic materials for packaging: A review

Emilien Freville %%1, Julia Pescheux Sergienko %1, Randy Mujica*, Candice Rey*, Julien Bras %5.**

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ARTICLEINFO

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ABSTRACT

Previousn-based parkaging howeveen levelaped during the bar convery is transport and generat many products, superdiment of the field of applications though devendurs, commonly issues, set. J. May proversion has been very model for the development of our storiky by furwing economic protech, limiting food wants and predent developments, and ensemportal proveding strong economic protech. Similary food wants and predent developments, and ensemportal proveding strong economics protech, the moviesment of converts has non-tertation time constroation by summerson economics, with wevers legislations being presemilying of to result of the photic wants. Is this noisely, encludes and applications thereing the strong applications done it is like towards. It is the stronger strong and applications thereing and and applications done it is like towards. It is the stronger strong results in the strong and lacend 30 consistences and in our . Howevee, more of the accessing acceleration is hand one and the local bar applications done in the like the stronger stronger

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Long-term research: FOCUS ON OPTIMIZING CELLULOSE MATERIALS THROUGH SPECIFIC FUNCTIONALITIES

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INVESTIGATION OF THE POWERS OF MECANOCHEMISTRY

Julia Pescheux-Sergienko, (Nov. 2021-Nov2024) PhD student. Co-supervision Pr Naceur Belgacem (Grenoble INP PAGORA) and Pr. Julien Bras, Chair Holder.

"New cellulose process for high-barrier specialty papers and 3D cellulose materials" Keywords: cellulose gel, blends of cellulose derivatives, new mechanochemically functionalized fibers, gas and liquid barrier.

The aim of this project is to investigate the different types of cellulose in order to maximise their barrier properties. The use of solubilised cellulose or nano-cellulose has the potential to act as a barrier to fats and oxygen. Chemical modification is envisaged as a solution for water and water vapour behaviour. The resulting materials will then be deposited onto different cellulose substrates and deposition techniques will be investigated as a function of substrate geometry and surface finish. The efficiency of the different «packaging» materials and their recyclability will be the focus of the project.





MATERIALS AND METHODS

- > Chemical modification by mechanochemistry
- Solubilization of cellulose
- Various coating techniques
- > Various characterizations (Cobb, WVTR, OTR, etc.;
- FTIR, XPS, EA, DRX, UV, DPv, etc.)
- Microscopy (Optical, Alicona, SEM)

MAIN RESULTS:

- Production of new cellulose derivatives
- > Multilayer coating on special papers
- > Investigation of coating on 3D objects
- (dip-coating, spray, tempography)
- > Recyclability of samples

PROSPECT:

- Continue along the path of mechanochemistry
 Investigate the deposition of solubilized cellulose on cellulose substrates
- Propose packaging solutions that take into account industrial realities (e.g. machinability) and current legislation (recyclability).

STUDY OF AN INNOVATIVE MULTILAYER MATERIAL DESIGN

René Rafael Romero.Lezama (Sept 2022-Sept 2025), PhD student. Co-supervision Dr Jeremie Viguié (research engineer, LGP2) & Dr Isabelle Desloges (associate professor, Grenoble INP PAGORA) and Pr. Julien Bras, Chair Holder.

"Multilayer cellulose process to produce high-value-added cellulose materials"

Keywords: cellulose, adhesion, active layer, encapsulation, mechanical properties, ply strength, barrier properties, recyclability.

CONTEXT AND OBJECTIVES:

This project, which is part of the Cellulose Valley Chair, aims to develop new cellulose-based multilayer structures for active packaging in collaboration with eight industrial partners. These structures consist of an active cellulose-based intermediate layer between two liner papers, which can be either barrier or non-barrier. The main objective is to study the effect of adding liner papers to these active layers to form two multilayer structures: active corrugated board and active cellulose foam for barrier shift.





Convolled release of curvacus

Active cellulose foam for barrier shift

Control of the relative-humidity insid-

MATERIALS AND METHODS

- > Fluting and liner papers
- > Cellulose foams
- Size press
- > UV spectroscopy
- > Microbiology activity
- > Water vapor transmission rate (WVTR)
- -> Wapor vapor absorption

MAIN RESULTS:

- > Decrease of release when adding non-barrier and barrier paper
- > Paper remains active after 10 days of release
- > Decrease of WVTR when adding non-barrier and barrier paper.

IMMERSIVE ANALYSIS IN PROCESSES FOR 3D CELLULOSIC PACKAGING: WET MOLDED FIBER

Mathilde Bernard-Catinat (Sept 2023-Sept 2026), PhD student. Co-supervision: Pr Evelyne Mauret (Grenoble INP PAGORA) and Pr. Julien Bras, Chair Holder.

"Innovative process for the production of 3D cellulose complex materials"

Keywords: cellulose, 3D proceed, Air-laid thermocompression, stretch paper, nanocellulose, barrier deposition on 3D form, spray, recyclability, life cycle analysis.

Since the late 1950s, the shift to a throwaway culture has led to extensive use of plastics in food, cosmetics and pharmaceutical packaging, causing serious environmental problems such as threats to wildlife, contamination of the food chain and climate change. New legislation aims to reduce plastic pollution by limiting production and promoting recyclable materials. Rigid items currently made from plastic, such as trays, bottle caps and disposable cutlery, can be made from cellulose. This thesis aims to develop innovative processes for the production of three-dimensional cellulose materials by comparing and proposing new 3D shaping and surface functionalisation techniques.





MATERIALS AND METHODS

- Compact multifunctional pulp molding machine and thermopress (WMF, DMF and WDD)
- Hammer crusher (DMF)
- Handsheet machine (WDD)
- > Paper pulp (several natural fiber sources).

MAIN RESULTS:

- Softwood pulp offers the best mechanical properties for WMF
- Higher water content offers better cohesion to DMF material
- > Wet handsheet can be 3D formed at low deformation depth.

PROSPECT:

- > Addition of new pulp tested
- Addition of moisture absorbing additives for DMF
- > Addition of wet strength additives for WDD.

STUDY OF STRETCHABLE PAPER TO PRODUCE 3D CELLULOSIC PACKAGING

Salomé Damour, Study enginner (2023-2024).

Co-supervision: Dr Jeremie Viguié, (research engineer, LGP2) and Pr. Julien Bras, Chair Holder.

"Investigation of paper with increased stretch potential for 3D forming"

Keywords: cellulose, plasticizer, physico-chemical interaction, role of anisotropy and moisture in cellulose elasticity, functionalization of cellulose and multilayers.

CONTEXT AND OBJECTIVES:

Plastic blisters are widely used for packaging pharmaceuticals, cosmetics and certain food products due to their lightweight and thermoformable properties. However, they pose significant environmental and health issues. Paper is a sustainable alternative as it is biodegradable, recyclable and reusable, but it has low extensibility which makes it difficult to thermoform for small deformations. This project aims to increase the extensibility of paper by influencing the fibres themselves, additives and the fibre network, in order to understand and control the operations required to produce extensible paper.





MATERIALS AND METHODS

> Paper pulp (BSKP)

- Additives (Guar gum, Alginic acid, Glycerol, Cellulose Nanocrystals, PAE resin) and enzymes
- Screen printer
- > Various drying methods
- > Thermopress.

MAIN RESULTS:

- Maximum elongation achieved by guar gum impregnation of an oven-dried handsheet.
- Possible thermoforming of guar gum handsheet on 1 cm deep mold.
- Possible 3D shaping of Screen printed CNC paper with defects.

PERSPECTIVES:

- Mechanical treatment of fibers to reach industrial paper extensibility
- Characterization of 3D formed substrates using topographical methods.

VALORISATION OF THE PROOFS OF CONCEPT

Candice Rey, Research engineer, (2023-2026). Supervion: Pr. Julien Bras, Chair Holder.

Project coordinator for short term research, partners contact person and valorization of the Cellulose Valley research

Keywords: proof of concept, scientific communication, project coordination, public knowledge diffusion, science valorization.

This organisation provides a dynamic research environment conducive to the rapid and efficient progression of research. The objective is to investigate fundamental cellulose-related themes that require a greater investment of time and expertise. This is the objective of doctoral and postdoctoral students. Concurrently, the master's degree students will assist in the confrontation of established models and ideas with the reality of the contemporary market, while also exploring alternative avenues for innovative thinking.

The detailed research results are accessible to the public via the chair website, presented in the form of a poster or reports.

The main objective of all research projects consists in exploring the intrinsic properties of cellulose and optimize its use as a finished material.

«The necessity to transition towards sustainable materials is a pressing issue in the present era. The strength of the Cellulose Valley Chair lies in its capacity to align research with the requirements of industrial production, thereby facilitating an ecological transition in production methods. The Chair's research projects offer our partners significant time savings, while the various exchanges between partners give a very tangible meaning to our research.»



THE EXPECTED RESULTS at the beginning of the chair are listed below:



- Improve the barrier properties of cellulose
 Explore multi-layer assembly of cellulose materials
 Investigate new industrial processes
- Propose innovative, recyclable and biodegradable materials
- Question **consumer habits** in terms of packaging and put forward solutions based on the **Life Cycle Analysis** of the products studied.

Innovation and SHORT-TERM SOLUTIONS

On the other hand, the 23 masters will address the most topical issues in the field, with a focus on rapid solutions and proofs of concept.

The subjects of these master's programs will be decided in agreement with each of the Chair's partners and discussed at the steering committee. A research engineer will be on hand to supervise and promote these projects.

BELOW ARE EXAMPLES OF THE MASTER STUDENT'S SUBJECTS FORECASTED:

 MFC as a reinforcement in corrugated cardboard
 Molded cellulose and recyclability, upcycling of recycled cellulose fibers

New cellulose beads for damping or high adsorption
 New cellulose injection prototypes
 Superhydrophobic solutions for e-commerce
 Super-light corrugated board for direct food packaging
 Alternative to fluorine for grease barriers

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omimetic approach to reusable board telligent molded cellulose with biopolymer coating nti-counterfeiting with transparent conductive ink dhesion measurement of multiple cellulose layers eat sealing and filling of cellulose packaging ellulose regeneration as a coating irect coating of solid/paste materials, etc.

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Demonstrator design BY THE SHORT TERM INNOVATION STUDENTS TEAM

PROTOTYPE EXAMPLES FROM 2023

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International COLLABORATIONS

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The Scientific Advisory Board proposed that the Chair should strongly considered scientific collaborations at international level.

The Chair would like to develop its partnerships by involving technical centers in its work. By the end of 2023, we plan to contact one of the following centers: EMPA, Innofibre (*Canada*), Bioproducts Institute (*Canada*), University of Maine (USA), VTT (*Finland*), Rise (*Sweden*).

In this context, the Chair has hosted the VTT technical center on June 28th 2023, for a day of exchanges and visits to the LGP2 laboratory. From this meeting a collaboration was born between one of the POC project and the VTT center. The project linked to Marie group allowed the student to visit the VTT and make some characterization during 10 days in may 2024.

The chair received also Elisbeth Jahn, a research assistant from the FH Campus Wien, in Austria. She exchanged with us on the plastics recyclability problematics and had the occasion to make a presentation in front of the LGP2 public. She learned how to perform recyclability test for papers and cardboards.

THE CHAIR ALSO WELCOMED SEVERAL INTERNATIONAL PHD STUDENTS DURING THIS PERIOD:



Università Foscari Venezi, Italy January-July 2024

Chemical functionalisation of cellulose materials and their use in the preparation of protective films.



Claire Stuppa

Université du Québec à Trois-Rivières, Québec, Canada October-December 2024

> Study of nano-suspensions / nano-wax emulsions



ITENE, Valencia, Spain November 2023-January 2024

Manufacture of nanocelluloses.



Ruby Osei-Bonsu

University of British Columbia, Canada September-November 2024

Improving the yield and colloidal stability of hydrolysed cellulose nanocrystals in subcritical water.

SHARING SCIENCE

All about (NOT NANO) CELLULOSE

The 9th June 2023 From 9:00 to 17:30

At UBC Campus, CHBE #202 2360 East Mall, Vancouver, BC V6T 124

A collaboration between the University of British Columbia (Canada) and the University of Grenoble Alpes (France) supported by the French embassy in Canada

AMBASSADE DE FRANCE AU CANADA

Т	ECHNICAL PROGRAM:	
09-00	Walcome coffee	
09:10	Opening speech	
09:20	UBC presentation	
09:30	LGP2 presentation	
09:40	Wood Foams for Thermal Insulation: Aqueous Stability, Thermal Conductivity, and Compression Strength	
10:10	A mix of HPMC/GG with cellulose fibres in a twin-screw extruder for thermocompressed cellulosic fibres material	
10:40	Coffee break	
10:50	Glycosylated tannins: from Bark Hydrocolloids to New Glycomaterials	
11:20	All about moulded cellulose and its functionalization	
11:50	The Applications of Biosurfactants	
12:20	Lunch	
14:00	Cellulose refining and fibrillation	
14:30	Multidimensional Fluorometry for Lignocellulosic and Beyond	
15:00	Will paper save the world?	
15:30	Coffee break	
15:45	Film Microtemplating and Surface Properties	
16:15	Cellulose Valley: new cellulosic-based solution for packaging	
16:45	Wrap-up presentation session	
17:30	UBC tour	
Contact Johan,F Julien,B	information: More info on: oster@UBC.ca https://bpi.ubc.ca/events/not-nano ras@Grenoble-INP.fr	



AU CANADA



Géraldine Dantelle Johan Foster Julien Bras Elizabeth Dobrzanski Emilien Fréville Gio Bautista Julia Pescheux-Sergienka Henrique Alves Arnaud Bénard Mahfuzul Hoque Gael Depres

amantha Pritchard Ilien Bras

UNIVERSITY OF

BRITISH



The visit of VTT pilot facilities, Graz University laboratories, Paper technical center in Ljubjana, embrapa facilities in Sao Carlos and department of paper in North Carolina State University has been useful to benchmarck our research and find complementarities.

A scientific exchange day was also organized at the University of British Columbia (UBC) in Vancouver on June 9, 2023, entitled "Not nano Cellulose". During this day, 5 UBC researchers and 5 Cellulose Valley members gave 30-minute presentations to share knowledge and advances concerning cellulose. The event was supported by the French Embassy in Canada.

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Conclusions AND NEXT STEPS OF THE CELLULOSE VALLEY

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MID TERM REPORT I 55



The objective of the Cellulose Valley chair is to engage in research and innovation pertaining to cellulose in the context of packaging applications, and to disseminate the resulting knowledge to the wider public.

Regarding long-term innovation, all the PhD students have been launched with success, and some disruptive ideas are in progress. A benchmark with international research has been done with numerous conference participation.

Concerning the short-term innovation, already 23 proofs of concept have been launched with some positives results for most of them.

Strong relationships with the partners has been built via these short-term projects with more than 50 meetings with all the partners. The perspective for these proofs of concept is technology transfer with partners for the best projects.

Strong actions with the society have been done by the Chair members, at some exhibitions, student engagement, and some other scientific events.

The Chair is also involved in some student project like literature survey, or engineering projects. The first two years the chair have been achieved as planned with lots of proactive actions and successful scientific discussions in agreement with the expectations of the Chair. Collaborations between some of our partners and with companies in contact with Julien Bras have been set up to scale up the proofs of concept developed by the Chair's students.

It is the Chair's hope that over the next two years, there will be a notable increase in interest in cellulose and a more sustainable industry among young engineers and students, with the objective of training the next generation for a successful environmental transition.

Aknowledgements & CREDITS

We would like to thank our partners and their involved colleagues for all the interesting discussions, guidances and advices into our commun projects. We are gratefull to our research colleagues from LGP2 and Grenoble-INP PAGORA for their scientific support and personal investigation into our different collaborations. The Chair members thank John Francis Kenwright, Francesco De Angelis and Perform platform for their support in our serious game project, Cellulose Valley – The Game.

The Cellulose Valley team would like to acknowledge Murielle Brachotte, Marie Dubrueil, Bernard Ugnon Coussoz, Benoit Giroud, and the Fondation Grenoble-INP for all their involvement and contributions. The Cellulose Valley is also gratefull to Grenoble-INP for their support in the process of creating the chair.

We thank Julia Pescheux-Sergienko, René Romero Lezama, and Mathilde Bernard-Catinat for being part of The Cellulose Valley's journey toward a sustainable future and making Science. We also thank them for their contribution to this report.

A special thanks to all the young researchers involved in the proofs of concept projects, who contributed to an important part of our research activities.

Redactions:

Candice Rey Julien Bras

Photo credits: Pierre Jayet – Fondation Grenoble INP

Design: Starteo - www.starteo.pro

Printing: Imprimerie Deval - www.imprimerie-deval.fr









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