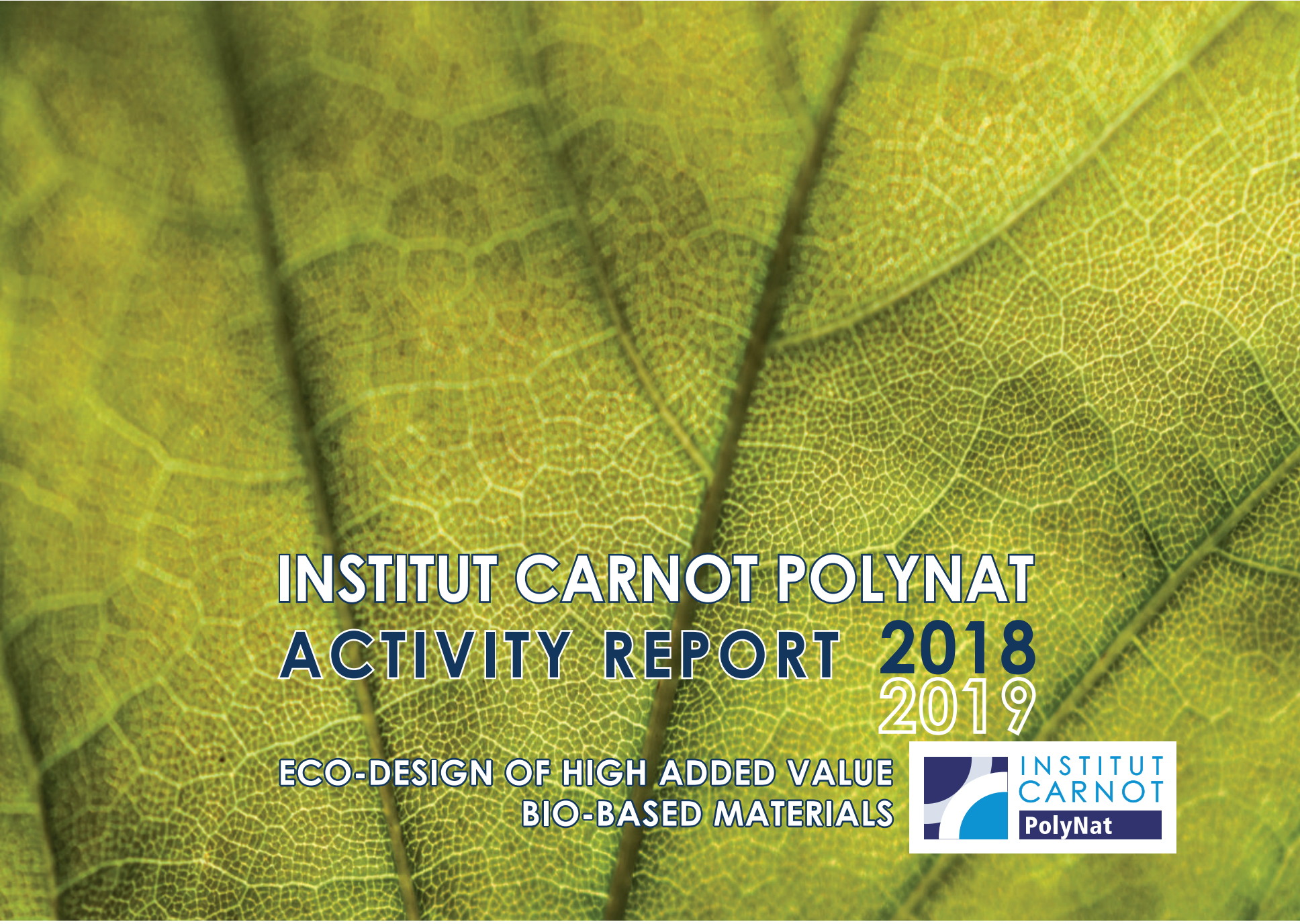


INSTITUT CARNOT POLYNAT
ACTIVITY REPORT 2018 2019

ECO-DESIGN OF HIGH ADDED VALUE BIO-BASED MATERIALS

INSTITUT CARNOT PolyNat

The extension of PolyNat's scope to new academic partners: the Department of Molecular Pharmacochemistry (DPM) and the Department of Molecular Chemistry (DCM) as well as a technical centre, the French Institute of Technology for Forest-based and Furniture Sectors (FCBA), has greatly contributed to strengthening and diversifying the scope of our Institute's potential applications.

Through their expertise in the fields of wood science, pharmaceutical chemistry, bioelectrochemistry and macrobiomolecular engineering, these new members bring complementary skills to those of the previous consortium, allowing the inclusion of building, transport and wooden furniture materials, and the expansion to new applications in health, diagnostics and electrical energy production.

We invite you to discover through the presentations of the 2018-2019 projects, the wide range of collaborative actions involving all partners. From basic materials such as lignin and cellulose, and elementary bricks such as nanocellulose, nanocrystals and cellulose microfibrils, proteins, carbohydrates and biosourced polymers, these projects are offering innovations and technological breakthroughs focused on high added value biosourced materials as alternatives to plastic materials.

In addition to recurring issues addressed on several successive projects such as lignin bleaching, this research extends to the production of paper and cardboard with barrier (water, O2, fats, mineral oils) or conductive properties, opening the way to food packaging, compostable materials or opto-electronic devices for screens or solar cells, to foams for the development of new materials as substitutes for petroleum-based polymers.

In addition to the moulding of wood as a thermoplastic, and the non-destructive dosage of wood preservatives, the achievements also include hybrid materials containing clays as new bio-based building materials or for pharmaceutical packaging, microfluidic platforms for self-powered medical devices, and ultrasonic wave powered microdevices for drug delivery.
During this year, these actions successfully led to the creation of two maturation projects at SATT: FunCell and BeFC.

Finally, we must also highlight the growing efforts of our Institute in terms of both internal and external communication. PolyNat's international openness is remarkable within the Carnot Institutes, illustrated by the annual establishment of an International Forum focusing on the participation of international industrialists, and also by pilot industrial projects in Asia and cooperation agreements with Taiwan.

In conclusion, it is clear that biodegradable biosourced materials produced using environmentally friendly processes are becoming increasingly popular, if not exponential. I wish you a good reading of this report and remind you that PolyNat's future depends on everyone's action and that it is your unfailing support that promotes our Institute.

Serge Cosnier,
Scientific Director

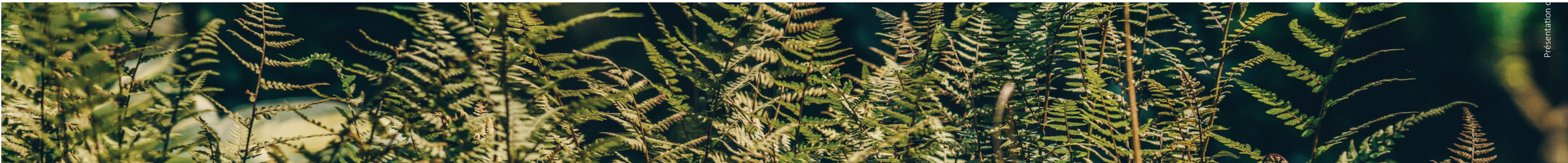
CONTENTS

1. PolyNat Presentation

The search for alternatives to fossil resources encourages the development of new materials and environmentally-friendly chemistry.

PolyNat aims to make the most of biomass to eco-designed functional and innovative bio-based materials.

The complementary expertise of the 8 Grenoble partners enables PolyNat to engage in partnership research throughout the value chain: from the functionalization of bio-based molecules, their controlled self-assembly, to the shaping of the materials obtained to pilot-scale prototyping.



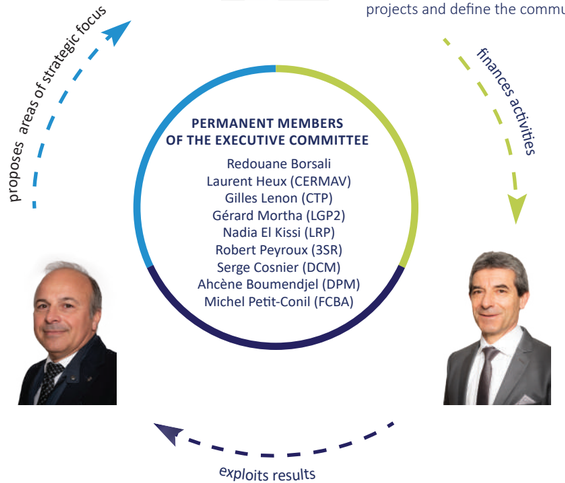
GOVERNANCE

To ensure a strong and balanced governance framework, PolyNat is managed by three committees, supported by the operational team:

EXECUTIVE COMMITTEE

Chaired by Redouane Borsali
Director of PolyNat

The **Executive Committee** is composed, in addition to the Director of PolyNat, of a representative from each partner organisation, and meets monthly.
The main tasks of this committee are to oversee the institute, coordinate the partnership-based research, validate the R&D projects and define the communication strategy.



STRATEGIC ORIENTATION COMMITTEE

Chaired by Gilles Lenon
Partnerships Director

This committee draws up strategies to exploit the results obtained during R&D projects funded by the Carnot institute. Drawing on business intelligence tools, it constantly monitors developments on the market in order to identify companies that could collaborate with PolyNat teams.

SCIENTIFIC COORDINATION COMMITTEE

Chaired by Serge Cosnier,
Scientific Director

This committee comprises the Director of the institute and two scientific representatives from each PolyNat partner. It meets twice a year, in autumn during examination of the projects submitted, and in spring during the 'PolyNat Days' to review the projects funded.

OPERATIONNAL TEAM

Sophie Renaud
Project manager
Coordination, management, communication

François Portier
Business developer
Customer relationships

EXPERTISE

The Institut Carnot PolyNat brings together the expertise of eight partners in the Grenoble area, covering an extremely wide range of fields:

TARGET MARKETS

CHEMICALS

- Environmentally friendly chemistry
- Development of eco-processes with lower impact on the environment
- Exploitation of the natural diversity of lignocellulosic resources

HEALTH AND COSMETICS

- Medical devices
- Extraction of functional macromolecules from vegetal resources
- Encapsulation and vectorization of bioactive molecules

PACKAGING AND INNOVATIVE PRINTS SUBSTRATES

- Flexible fibrous supports
- Intelligent, functional, connected, more efficient packaging
- Barrier properties (water, EM waves, etc.)
- Flexible nanoelectronics, printed electronics
- Bioelectronics and IOT

ENERGY AND TRANSPORT

- New sources of energy: industrial co-products, bio-based batteries, biofuel cells
- Mechanical performances (lightness, robustness …) reinforced by nano-micro functionalized fibers
- Functional Properties
- Decrease the environmental impact

WOOD BUILDING AND FURNITURE

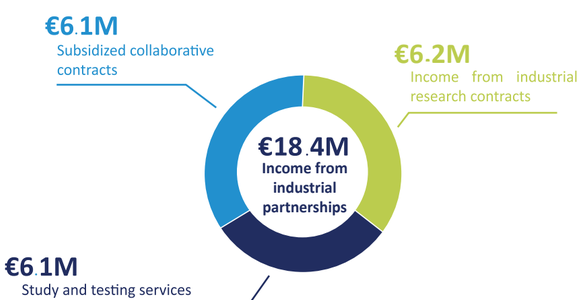
- Biosourced glues and varnishes
- Biomaterials shaping
- Selective barrier properties
- Control of the thermo-hygromechanical behavior of materials
- Biosensors, Plastronics, Composites, Modelization

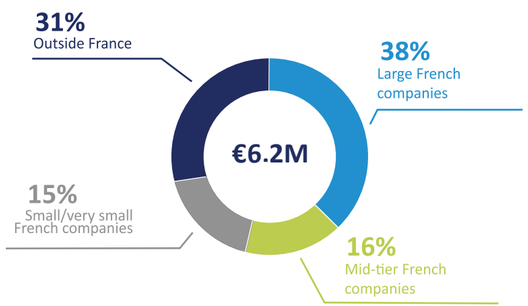
KEY FIGURES 2018

400 patents held in our portfolio

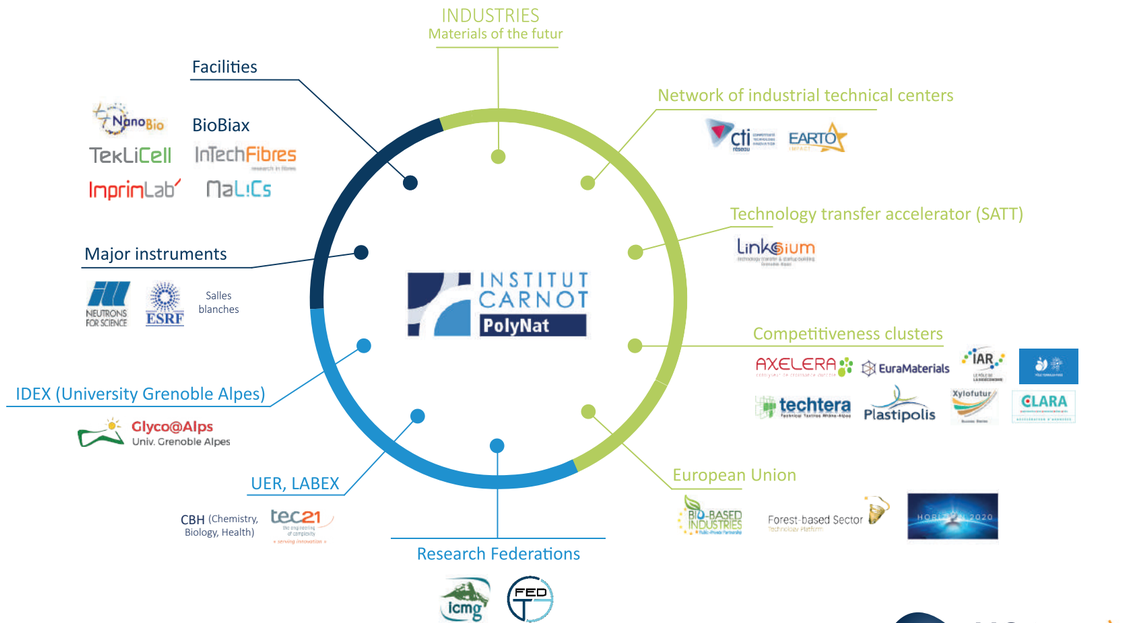
200 A-ranking publications

400 research employees of whom **110** PhD students





POLYNAT AND ITS ENVIRONMENT



2. Carnot Network

What is the Carnot network?

The Carnot network is a **network of multi-disciplinary research institutes** with strong local bases whose goal is to transfer technologies and drive business innovation.

Each institute probated by the Carnot label undertakes to conduct and develop its R&D activities to boost industrial innovation. This label guarantees **scientific excellence and professionalism in the partnership :**

- A high scientific and technological expertise
- A professional conduct of the partnership
- A structured network facilitating access to all skills and technological platforms at national level
- A tailor-made offer, whatever the size of the company and its sector of activity

Professional approach to confidentiality management

Transparent and balanced intellectual property and licence transfer policy

Consideration of the regulatory requirements at each stage of development

Carnot network : 2018 key figures

38 Carnot representing

50% of the R&D funded by companies in French public research

i.e. **9,000** research contracts per year

Association INSTITUTS CARNOT

Find out more : www.instituts-carnot.eu

3. RESEARCH

SCIENTIFIC CHALLENGES

To back up its strategy of developing partnership-based activities, each year PolyNat finances R&D projects with industrial potential sponsored by teams from at least two of its member laboratories.

Each project must aim to generate new knowledge or validate new concepts in order to develop our scientific and technological offer, in accordance with industrial companies' expectations and their commitment to promote the bioeconomy via collaborative programs or direct partnerships. These actions correspond to one or more of the four scientific challenges that PolyNat has identified:

4 scientific challenges

CHALLENGE 1

Biosourced building blocks: extraction and characterization

- Oligosaccharides, glycopolymers, biopolymers, nanocellulose, cellulose fibres;
- Extraction, purification and separation processes;
- Use of "green" solvents and low-energy processes

CHALLENGE 2

Building blocks and materials functionalization for targeted innovative properties

- Chemical and/or enzymatic modifications or physical treatments of biosourced (macro)molecules;
- Design of biosourced devices with innovative properties: hydrophobic, anti-microbial, bionano-electronic, etc.

CHALLENGE 3

Controlled self-assembly and nano-organization

- Directed self-assembly of biosourced building blocks;
- Innovative processes to obtain nano-structured materials: nanoprecipitation, spin- or dip-coating;
- Development of smart surfaces, three-dimensional materials, and functionalized and multi-compartmentalized glyco-nanoparticles

CHALLENGE 4

Production and development processes of biosourced materials

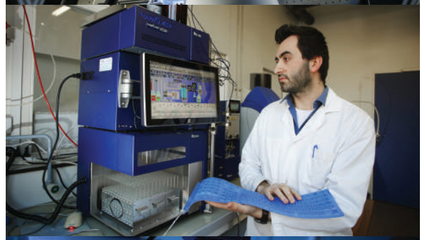
- Adapting or developing techniques that foster industrial transfer
- Understanding interactions at interfaces for an advanced design of biosourced devices

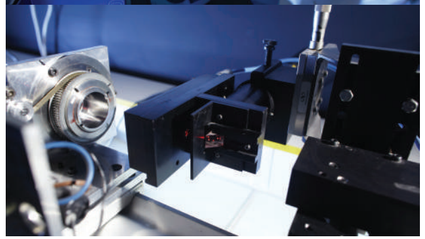
Proof of concept: from the laboratory to pilot plant

PolyNat aims to produce biomaterials at pilot scale.
Each development step takes into account the regulatory and environmental requirements.

Modelling, simulation and characterization resources

For each of these challenges, the research performed is based on the development or adaptation of approaches combining experimental characterization, modelling and simulation.



FACILITIES AND INSTRUMENTS

NanoBio icmg

Leading edge technological resources in the field of **nanosciences**

TekLiCell

Industrial-scale equipment for **smart paper/printing of the future, biomaterials, bioenergies and bioprocesses**

BioBiax

Bose **biaxial press for thermo-hygro-mechanical characterization** of bio-based material

InTechFibres

Equipement and devices for the production **of functionalized lignocellulosic fibres** and particles and the shaping of **wood panels**

MaLiCs

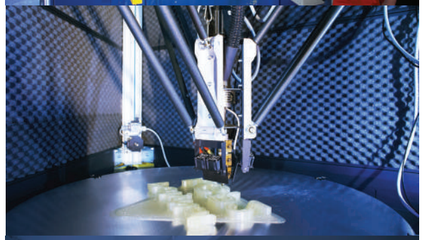
Developing innovative solutions for **tomorrow's packaging**

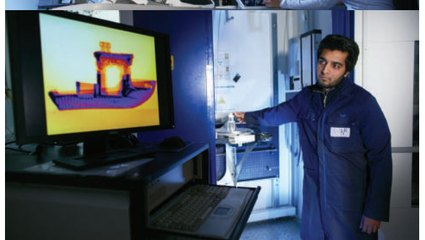
ImprimLab

An innovation cluster specialising in **printed electronics** for **printing and converting firms**

ESRF NEUTRONS FOR SCIENCE

PolyNat is a stakeholder in various scientific facilities in the Grenoble area, and has special access to **major instruments used for imaging and modelling** down to the nanoscale



PROJECTS FUNDED

RESOURCE BUDGET

2018

11 projects funded

Budget

€ 745,300

2019

10 projects funded

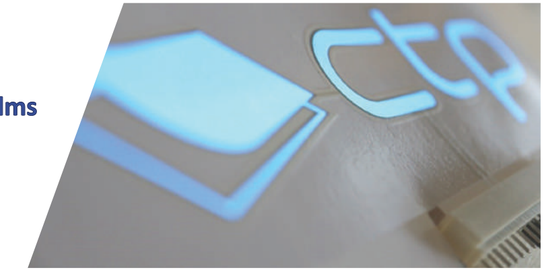
Budget

€ 750,500

2018 PROJECTS

GLYCOPV

Bio-based **nanostructured films** for **OPV** devices



PROJECT

Many printed electronics applications, such as display, lighting or solar cells, require a transparent substrate.

In order to promote the use of bio-sourced materials to replace petroleum-based plastic in these high-tech applications, our objective is to develop transparent and electrically conductive cellulosic substrates and then to demonstrate some opto-electronic devices.

RESULTS

First, we made perfectly smooth and transparent sheets by depositing coatings of polymers with suitable optical index on sheets of cellulose nanofibres.

At the same time, we have developed 2 distinct opto-electronic devices to highlight the advantages of natural plant-based materials. The first demonstrator is an electroluminescent display printed on different types of papers, opaque or transparent. The second demonstrator is a Perovskite solar cell, whose efficiency is optimized through the use of sugar-based copolymer blocks, which allow the active layer to self-organize at the nano-scale level.

PROJECT TEAM

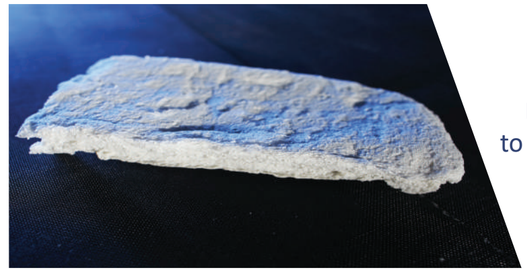
PROJECT LEAD
Redouane Borsali - Research Director
CERMAV

PARTNERS
CTP- Davy Soysouvanh

TARGET MARKETS

Packaging and innovative print substrates

Large-area flexible electronics applications: interactive wallpapers, photovoltaic panels, smart packaging ...



SUBIOFOAMS

Elaboration of **foams** to develop **new cellular materials**

PROJECT

Through three projects funded by PolyNat (Microfoam, Cellufoam and SubioFoams), our teams are developing bio-sourced foams with similar characteristics to the oil-sourced foams conventionally used in packaging to improve impact resistance, compressive strength or can be used as thermal insulator (expanded polystyrene, polyurethane).

RESULTS

To generate foams, they formulated suspensions based on micro-fibrillated cellulose (MFC) and identified the most appropriate foaming technique.

They managed to develop fully instrumented foam generator pilots, that enable the continuous production of stable foams with controlled aeration rates.

The teams are now studying the appropriate drying technologies in order to obtain a process that can be scaled up for the industrial production of bio-sourced foams and able to compete with their oil-sourced equivalents.

PROJECT TEAM

PROJECT LEAD
Emeline Talansier- Lecturer
LRP

PARTNERS
LGP2 - Davide Beneventi, Martine Rueff, Evelyne Mauret,
CTP- Elisa Zeno, Bruno Carré

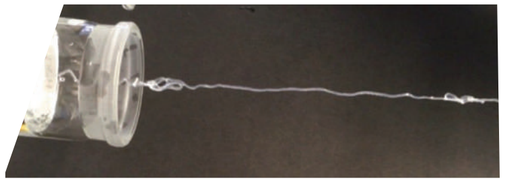
TARGET MARKETS

Packaging and innovative print substrates

Shock, compression and thermal insulating packaging

DISSOLUCELL

Cellulose Dissolution



PROJECT

The global demand for textile fibers is continuously increasing. Bio-based fibers are a serious alternative to petro-based synthetic fibers.

This project aims to develop an innovative and green process for the solubilization of cellulose in aqueous medium at room temperature, to replace the existing Viscose and LyoCell processes, to obtain bio-based textile yarns from wood cellulose.

RESULTS

In order to improve the solubilization of cellulose in aqueous media, the cellulose has been functionalized by grafting hydrophilic carboxyl groups, by an oxidative treatment, associated with additional treatments carried out prior to or during the oxidation.
The ionization of the COOH groups should favor the individualization of the cellulose chains in an aqueous medium.

The oxidation of the cellulose with the NaIO4/NaClO2 sequence, combined with prior mercerization, made it possible to obtain complete dissolution in caustic soda solution (5% pulp, 10% NaOH) and at room temperature. The decrease in the value of DPv remained moderate (final DPv 255), for a grafting of COOH groups leading to a very low degree of substitution (DS of 0.08).

Despite the fact that these threads are obtained without any stretching and are still filled with water, they appear to have a good tensile strength that will be characterized further. The same conditions of oxidation and dissolution were applied to celluloses of different origin, and also led to the regeneration of threads which could be handled.

PROJECT TEAM

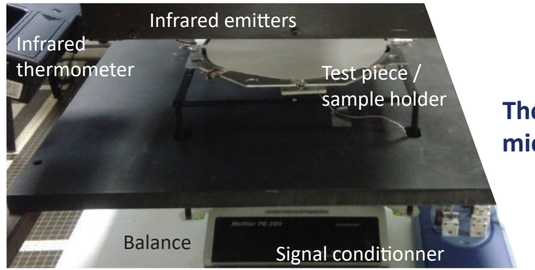
PROJECT LEAD
Bruno Carré - «Structuring of materials» team manager
CTP

PARTNERS
CTP - Elisa Zeno
LGP2 - Dominique Lachenal

TARGET MARKETS

Packaging and innovative print substrates

Textile industry, paper industry



THERMIC

Thermal properties of wet cellulose microfibrils films and drying strategy of wet laminated cardboard

PROJECT

Cellulose microfibrils (CMF) have a high potential for the production of oxygen, grease and mineral oil barrier layers with applications in the field of packaging, in order to replace petroleum-based layers.

The CTP and the CNRS have developed an alternative method for depositing and bonding a layer of CMF on a cardboard substrate. The nature of the coating material is similar to a hydrogel, whose properties differ from the mineral coating layers used in the manufacture of coated papers.

The final goal of the TherMiC project is to determine the relevant means for drying such a laminate material. For this purpose, a study of the phenomena taking place was carried out, based on experiments at the laboratory scale and compared to pilot trials.

RESULTS

The TherMiC project enabled us to carry out a fundamental work in order to provide the necessary knowledge to select the relevant drying technologies.

The main involved mechanisms were identified and the values of the corresponding physical quantities were determined. For instance, it was found, at the laboratory scale, that the drying kinetics was limited by the external conditions and not by the material properties, in the range explored.

Thus, a strategy for drying CMF laminated on a cardboard was proposed.

PROJECT TEAM

PROJECT LEAD
Arnaud Aubigny - Energy project manager
CTP

PARTNERS
LGP2 - Davide Beneventi, Martine Rueff, Evelyne Mauret,
CTP - Elisa Zeno, Bruno Carré

TARGET MARKETS

Packaging and innovative print substrates

VALONOIX

Identification of **recovering ways for walnut shells**

PROJECT

This project is interested in the development of the Grenoble walnut shell, a local plant source, which has not yet been studied and exploited, and is a potential source of high value-added molecules.

The first method of recovery is molecular. The project aims to identify the chemical constituents of interest of this biomass, with an in-depth study of biologically active extractives in the therapeutic and cosmetic fields.

The second recovery method is based on the exploitation of residual biomass after extraction in the field of biomaterials to produce packaging materials and panels for construction or furniture.

RESULTS

The evaluation on different pharmacological tests of these extracts demonstrated their absence of toxicity but did not result in a significant biological activity.

The use of nut shells in panel-type materials, preserves or improves mechanical properties, water swelling is lower and preliminary results suggest interesting fire behavior.

Finally, the addition of finely ground nut shells in paper (10% w/w) does not alter the mechanical properties of the paper without increasing the barrier properties to liquid water

PROJECT TEAM

PROJECT LEAD
Benjamin Boucherle - Lecturer
DPM

PARTNERS
FCBA- Sandra Tapin-Lingua
CTP- Valérie Meyer,
Mohammed Krouit

TARGET MARKETS

Wood building and furnitures

Production of mixed nut shell/wood materials for furniture and building applications

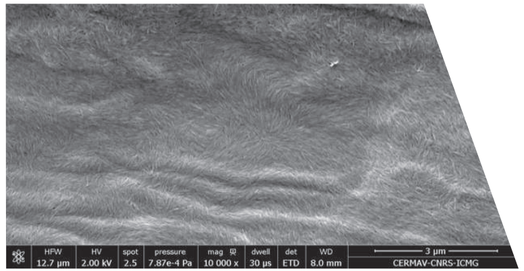


Image : SEM image of the surface of a (GNP/CNC) multilayered coating onto a kraft cardboard

FILHYBAR

Hybrid cellulose nanocrystals/ gibbsite nanoplatelets **multilayered coatings** for **oxygen barrier improvement**

PROJECT

Nanocelluloses are likely to play a major role in the packaging sector due to their ability to form gas barrier coatings. Moreover, their combination with inorganic nanoplatelets via the use of the layer-by-layer assembly method (LbL) makes it possible to produce dense and cohesive structures that exhibit a high degree of tortuosity.

In this context, the objective of the FILHYBAR project was to investigate the possibility of covering commercial substrates (modified or non-modified paper or board, plastic films) with thin multilayer hybrid films composed of alternating layers of cellulose nanocrystals (CNC) and gibbsite mineral nanoplatelets (GNP) in order to improve their oxygen and water vapor barrier properties.

RESULTS

First, the LbL process, initially developed for small rigid and smooth surfaces, has been adapted to the use of flexible and large substrates.

Through the use of advanced structural characterization methods (ellipsometry, AFM, scanning electron microscopy), we then showed that multilayered (GNP / CNC) films could be deposited on the surface of all investigated substrates, irrespective of their composition, surface morphology, roughness and hydrophilicity, with a dense and homogeneous architecture identical to that obtained on model substrates.

Finally, for defect-free commercial substrates, we have been able to obtain thanks to these coatings a significant improvement of the oxygen barrier properties with up to a 75% reduction in permeability relative to the bare substrate.

PROJECT TEAM

PROJECT LEAD
Bruno Jean- Researcher
CERMAV

PARTNERS
CTP- Laura Crowther-Alwyn,
David Guérin

TARGET MARKETS

Packaging and innovative print substrates

Food and pharmaceutical packaging

DISOLI

Control and optimisation of the **dispersion/solubilisation of lignin particles**

PROJECT

Kraft lignins are the main by-products of chemical pulp mills. Still mainly used for energy, however they have a three-dimensional phenolic structure and interesting physicochemical properties for the development of bio-sourced materials/products. In the form of fine and hygroscopic powder, Kraft lignins are classified ATEX, which greatly limits its applications, especially solubilization/re-slurrying in water.

The DISOLI project focused on improving the utilization properties of Kraft lignins by optimizing particle size and structure. It aimed to develop a process of wet granulation of fine Kraft lignin powder, using preferably a binder favoring its later dispersion.

RESULTS

Lignosulphonates (lignins produced by sulphite processes), already used as binders, have been advantageously used on softwood kraft lignins (particles ~ 20 µm, passable flowability) and hardwoods (particles ~ 3 µm, bad flowability), to produce 100% lignin grains.

Granulation was particularly efficient on hardwood kraft lignins, and led to homogeneous grains of size ~ 3 mm, with an excellent flowability, and keeping the initial properties of kraft lignins.

PROJECT TEAM

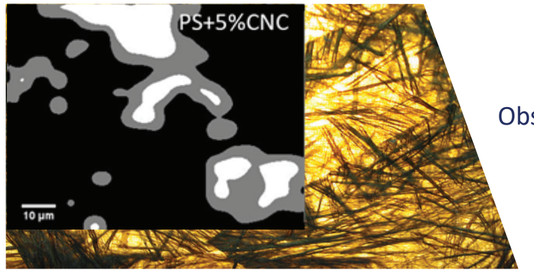
PROJECT LEAD
Frédérique Bertaud - Research engineer
CTP

PARTNERS
FCBA - Sandra Tapin-Lingua
CERMAV - Sonia Molina-Boisseau

TARGET MARKETS

Chemicals/ Wood building and furnitures

Bio-sourced materials / products based on lignins



CELLMAP

Observation of the orientation of **CELL**ulose nanocrystals during the extrusion process: effect of the **P**olymer **MA**trice

PROJECT

Cellulose nanocrystals (CNC) are biosourced fillers that, added to polymer matrices, allow a significant improvement in their mechanical properties.

For this, it is necessary to have a homogeneous dispersion of the CNCs. If this is easy by casting-evaporation processes, obtaining such a dispersion by industrial processes offers one of the interesting challenges of recent years. Though, despite numerous studies on CNCs, there is currently no satisfactory method for mapping CNCs within a polymer matrix. However, it is essential to be able to visualize these fillers in order to understand the phenomena of dispersion and orientation.

In this study, we will focus on sampling and visualization techniques using Raman spectroscopy to map the dispersion of CNCs and quantify their orientation.

RESULTS

The Raman spectra obtained allowed us to make a differentiated analysis and to obtain a contrasting image of our samples. The highest intensities indicate the presence of cellulose, the darker zones being representative of the polymer matrix. The area and percentage of area occupied by each of the components in the sample could then be estimated by software developed at the LRP.

This study reveals the existence of two antagonistic processes that take place during the incorporation of CNC into a polymer matrix; the aggregation process and the mixing process. Our data also makes it possible to quantify these processes. Finally, note that the ratio of agglomerated CNCs to CNCs mixed with the polymer matrix can be used as an aggregation indicator.

PROJECT TEAM

PROJECT LEAD
Nadia El Kissi- Research director
LRP

PARTNERS
LGP2 - Alain Dufresne

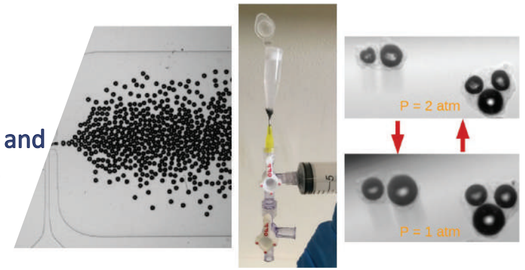
TARGET MARKETS

Packaging and innovative print substrates / Health and cosmetics

Packaging- Energy

CELLUSWIM

Fabrication of **biosourced microswimmers**, powered and steered by ultrasonic waves



PROJECT

Commonly used drug targeting strategies are based on molecular recognition concepts that could be described as «passive». The players in the pharmaceutical sector are very much in demand for innovative solutions in this field.

This project aims to explore the possibilities offered by certain physical phenomena to actively control delivery. From a technological point of view, it aims to propel air-filled hulls into a liquid medium, via mechanical instabilities generated by pressure cycles inducing deflation («buckling») and re-swelling.

RESULTS

The project results from sharing skills in continuum mechanics, microfluidics and chemical physics. We have settled a reproducible protocol during which air bubbles were covered with a cellulose nanocrystals (CNC) + xyloglucan (Xg) coating.

Micronic bubbles were obtained in a microfluidic circuit, then wrapped with CNC or Xg layers by contact with the suspensions of interest, followed by a rinsing. When external pressure increased, the objects unswelled through a deformation indicating the solid nature of the shell. Furthermore, the deformation was reversible, hence pointing its elastic nature.

The obtention of such objects allows to forecast unswelling-reswelling cycles under ultrasonic waves, which is a necessary condition to induce a swimming motion remotely tunable.

PROJECT TEAM

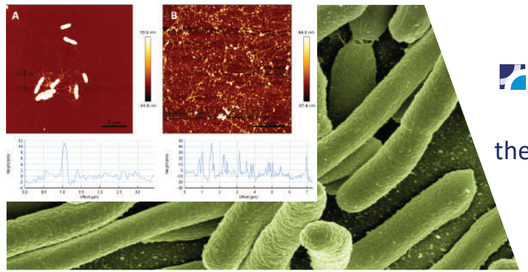
PROJECT LEAD
Catherine Quilliet - Lecturer
LIPhy

PARTNERS
LIPhy - Gwennou Coupier,
Elise Lorenceau, Philippe Marmottant
CERMAV - Laurent Heux, Yotam Navon

TARGET MARKETS

Health and cosmetics

Remotely actuated microrobots in fluid medium, targetted drug delivery



PSEUDOLECTINS

Investigating the role of **lectins** in **bacterial virulence**

PROJECT

The widespread opportunistic pathogen Pseudomonas aeruginosa often exerts its virulence via the formation of biofilms on surfaces-organized structures where an extracellular matrix binds and protects bacteria. *P. aeruginosa* produces two tetravalent lectins (proteins that specifically bind sugars); blocking these lectins with glycomimetic compounds greatly reduces virulence, but the mechanisms involved are unclear.

The goal of this project is to use atomic force microscopy (AFM) and single molecule force spectroscopy to elucidate the role of lectins in biofilm construction, by directly measuring lectin-matrix interactions.

RESULTS

The work has two phases: we first need to image bacteria and their early matrix deposits by AFM. Then, we will move on to single molecule force spectroscopy, for which AFM tips will be functionalized by lectins, and brought into contact with the matrix in order to measure adhesion forces.

In situ imaging of live bacteria in liquid medium is tricky, but we have obtained encouraging first results (figure). The functionalization of AFM tips by lectins is in progress.

PROJECT TEAM

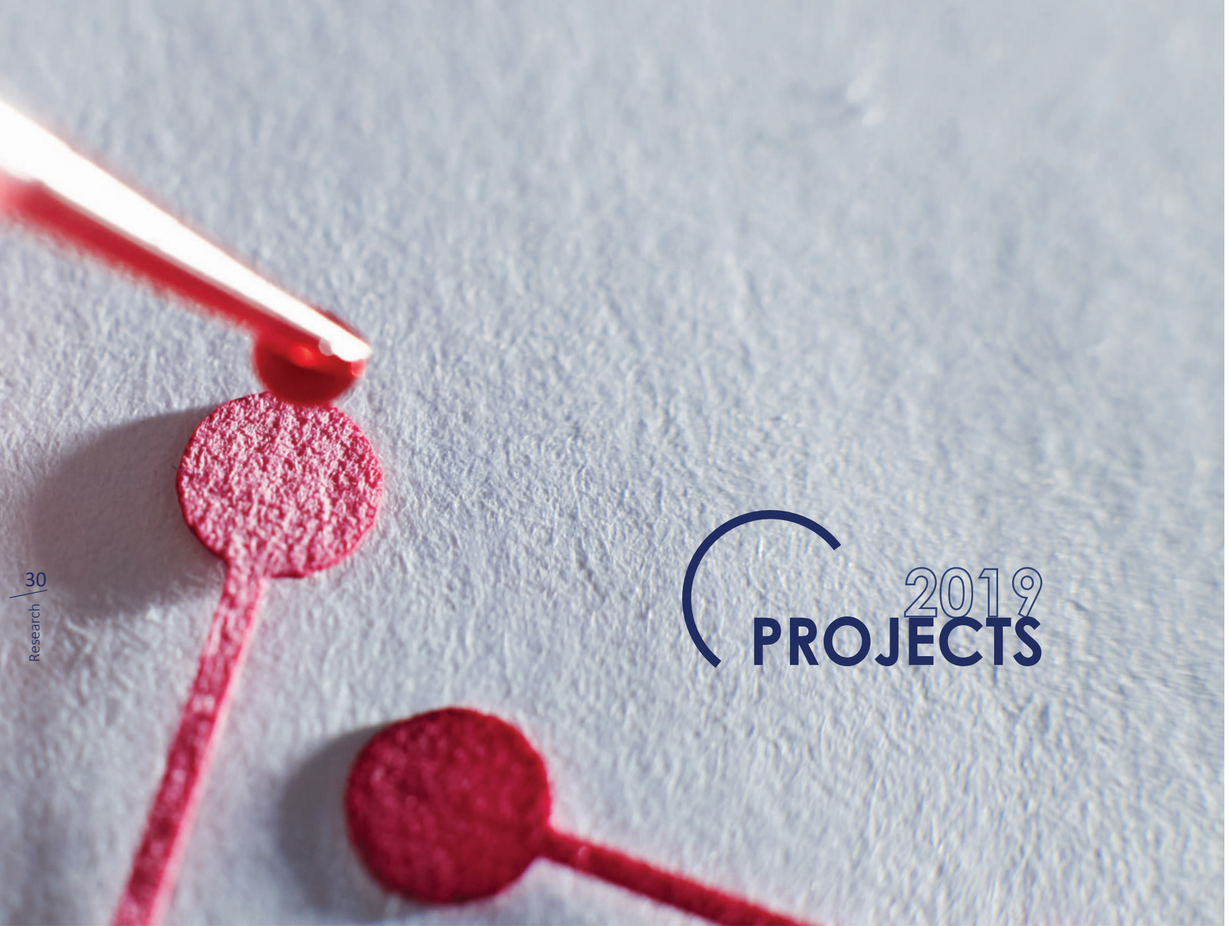
PROJECT LEAD
Sigolène Lecuyer Jean- Researcher
LIPhy

PARTNERS
CERMAV- Annabelle Varrot

TARGET MARKETS

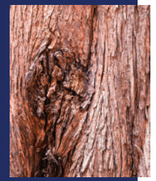
Health and cosmetics

Healthcare, biomaterials (implants, catheters), pharmaceutical industry



2019 PROJECTS

FUNDED PROJECTS 2019



APTABOIS

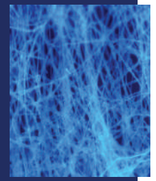
Development of **Apta**mers for in-situ characterization of molecules in **wood**

Pesticides, like tebuconazole, are toxic compounds used as wood preservatives. The techniques employed so far for their detection involve destructive methods (e.g. HPLC) or are immuno-based, difficult to produce against such small molecules. The aim of this project is to develop a proof of concept for an alternative in-situ characterisation of molecules on wood-based products using aptamers.

BIOWET

Biobased solutions for **wet** strength additives

One of the barriers to the use of paper in many applications is the collapse of its mechanical properties in the presence of water. The additives currently used to provide moisture resistance are petroleum-based, environmentally toxic and complicated to use.
The BIOWET project explores the mechanisms and use properties conferred on different types of cellulosic substrates by these additives in the context of their use in paper processes.

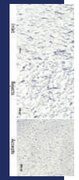


CHEM-MFC

A New **Chemical Platform** for the Pre- and Post-treatment of **functional MFC**

The production of cellulose microfibrils (MFC) from wood pulp and at low cost is today a real economic challenge and the prospects for multiple applications (composite materials, paper, packaging, textile, filtration, medicine, coatings and electronics). The CHEM-MFC project proposes to pre- or post-functionalize the oxidized cellulose fibers by the Knoevenagel condensation through a modulable chemical platform. Thus, we will incorporate various useful functions for (re) MFC dispersion or to improve their compatibility in polymer matrices or to exhibit biological activity.

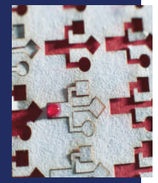
FUNDED PROJECTS 2019



CODEMFC

Evaluation of stress developed during the **drying of board** laminated with a **wet layer of MFC** and **modelling** of the porous structure of the MFC layer

CTP and CNRS patented the wet lamination of MFC concept, which can be used to laminate without glue an MFC layer onto the surface of a cellulosic substrate, and appears as a very promising alternative. However, several phenomena are yet not well understood: shrinkage during drying and adhesion of the MFC layer to the substrate, and the excellent barrier performances obtained despite the porous structure of the layer. A better understanding of these phenomena is essential for future packaging developments including this kind of layers.



LAMCELL-µPAD

All cellulose **micro-fluidic** strip for **analytical devices** obtained by wet-lamination, with integrated **enzymatic battery**

Classical paper-based analytical tests generally comprise a paper substrate that is further modified to define the capillary path : this makes it possible to convey the fluid from the reservoir to the test zone. The innovation is to use an MFC (micro-fibrillated cellulose) film as a water barrier to confine the displacement of the liquid. The device consists mainly of un-modified cellulose. The objective of the project is to develop an all-cellulose substrate for lowtech/low-cost micro-fluidics.

NACECO

Valorization of **na**no**ce**lluloses at high **co**ncentrations

Recent developments in cellulosic nanoparticle research have resulted in a vast literature on nanocellulose which is no longer just a topical issue but now an industrial reality. Their industrial production has taken a big step in the last two years with more and more companies around the world announcing the production and sale of these materials. That is why this project will focus on a new «type» of nanofibrils developed by PolyNat and Tec21 (CERISE project) and which can be defined as a high concentration nanocelluloses grade (20%).

FUNDED PROJECTS 2019

POLYCELL

Process for the **production of polyvalent celluloses** by **unconventional oxidation**

The PolyCell project aims to produce, from the same process, bleached kraft pulp but also high value added celluloses (dissolving pulp and pulp for MFC), by enriching in carboxyl groups the industrial paper pulps during the last bleaching stage. The innovation lies in the use of an oxidant, conventionally used in pulp bleaching lines, ClO_2, by studying operating conditions completely new for the paper industry. The multi-scale characterization of oxidized and deconstructed celluloses will allow qualifying and optimizing these new chemical treatments.

SUBWAT-MFC

Pre-treatment of **cellulosic fibres** in **subcritical water** **f**or the **production** of **cellulose microfibrils**

The objective of the project is to use a new eco-friendly designed cellulosic fibre pre-treatment process for the production of cellulose microfibrils (MFC) using subcritical water. Currently various processes have been optimized to pre-treat cellulosic fibers in order to weaken their structure for the release of microfibrils but they still have many disadvantages. The use of subcritical water as a new fibre pre-treatment process could overcome these limitations.

BROCOLI

Controlled Bulk production of **Cellulose Oligomers**

Cellulose oligomer, low molecular weight (MW) cellulose, shows high potential in high value-added applications such as food additives and amphiphilic compounds thanks to its good processability and amphiphilic nature. However, the use of cellulose oligomer is largely constrained due to its high production cost and poor availability. In the BroCOli project, we aim at enabling bulk production of cellulose oligomers with desired MW and MW distribution via concentrated acid hydrolysis of high-MW cellulose.

FUNDED PROJECTS 2019

TERRANOVA

Clay, plant fibres and biopolymers for **new building elements**

Clay has always been used as a building material, often combined with natural fibres to give improve physical properties. The different local construction cultures have given rise to biosourced materials and implementation processes that make it possible to have coatings or building elements with properties remarkably adapted to their environment; these old technologies have become sources of inspiration in our current quest for more sustainable development. However, few scientific studies have been conducted to analyze and understand the mechanical, hygro-thermal or acoustic functioning of these materials.

TWM

Thermo-hydromechanical **W**ood **M**olding

Wood is a nanocomposite made of crystalline cellulose embedded in amorphous matrix of hemicellulose and lignin, and thus have intrinsically high stiffness and chemical resistance and light weight adapted for many structural applications, from small casings to buildings. On the other hand wood behaves brittle in tensile deformation allowing only a few percent of elongation. The rigidity and the brittleness are the fundamental difficulties in industrial processing of wood. Traditionally, wood has been bend-processed by steaming and external restriction of elongation. Inspired by this artisanal process, we study the fundamental mechanical behavior of wood with plasticizer (water) and elevated temperature, for rational molding processing of wood.

LIGN'OR

Lignines fonctionnalisées par des réactifs **o**xydants ou **r**éducteurs

The interest of using lignin as a raw material has increased considerably recently. However, its use is often made difficult by the lack of reactivity and the strong colouring caused by the industrial production of paper pulp. In this project, we are developing processes for functionalizing lignin on different industrial hardwood and softwood lignins using oxidizing or reducing approaches. As these different treatments are likely to modify the structure of lignins, they will be thoroughly characterized and tested in several applications.

BeFC

Reinventing the way we power **wearable/disposable electronics** for a **sustainable future**

PROJECT

This project, financed in 2018 by PolyNat under the name of BigPad, aimed to develop a bio-power generator respecting the environment and able to supply disposable electrochemical devices like pregnancy or ovulation tests.

Today the start-up is maturing at SATT Linksium (Technology Transfer Accelerator Office) under the name BeFC. A contract is already underway with Swiss Precision Diagnostics (Clearbue), and three patent applications have been submitted.
BeFC has just won the Leyton sustainable start-up challenge and the opportunity to participate in the CES: the world's largest technology exhibition.

https://befc.fr/ BeFC Bioenzymatic Fuel Cells @BeFC_fr

PRODUCT

Our glucose biopiles consist of non-toxic and biodegradable components, and the fuel is even edible. These electric power generators can be operated with justa drop of natural fluides or tap water. They are therefore a good alternative to button batteries for disposable devices.

Many applications are being considered, such as ovulation/pregnancy tests, tests for home patient monitoring, or the Internet Of Things (IoT, connected sensors).

Ultra-thin paper energy source

Eco-designed and bio-based

Available in a wide range
of formats and performances

4. HIGHLIGHTS

HIGHLIGHTS

11th edition of the Carnot Meetings

OCTOBER 17-18th 2018

NOVEMBER 20th 2018

Redouane Borsali and Wen-Chang Chen receive the 2018 award of the French-Taiwanese Scientific Foundation

Under the dome of the Institut de France, Redouane Borsali, director of PolyNat Carnot Institute, and Wen-Chang Chen, Distinguished Professor at the National Taiwan University, received the Franco-Taiwanese prize for their collaboration on transistor memory devices.

Innovation Showroom, ATIP conference, Alpexpo Grenoble

The 4th meetings of the Paper Union took place in November in Grenoble during the 71st Congress of the Technical Association of the Paper Industry (ATIP). These meetings, organized in collaboration with CTP and LGP2/Pagora, focused on «technological challenges for the paper industry of the future». Gilles Lenon (Director of CTP) and Didier Chaussy (Director of LGP2) presented the eco-processes and eco-products of tomorrow.

NOVEMBER 20-21st 2018

MARCH 5-8th 2019

Global Industrie

PolyNat was present at the Global Industrie exhibition on the «Carnot» pavilion, meeting companies to present the skills of its partners.

5th edition of the International Industries Forum and Visiting Committee

MAY 14-15th 2019

MAY 24th 2019

Biosourced and innovative materials Grenoble Tour

The industrialists participating in the Plant Based Summit exhibition were invited to visit CTP, LGP2, CERMAV and 3SR during a day co-organised by PolyNat, PBS, Grenoble-Alpes Metropole and the Axelera cluster.

Julien Bras receives the NanoDivision Mid-Career Award 2019

This award was presented to him by TAPPI NanoDivision for his outstanding contribution to research on renewable nanomaterials, in less than twenty years of career.

JUNE 3-7th 2019

JUNE 26-27th 2019

7th edition of the PolyNat Days

12th edition of the Carnot Meetings

OCTOBER 16-17th 2019

RENDEZ-VOUS CARNOT

The «Rendez-Vous Carnot» (Carnot Meetings) are unmissable opportunities to meet businesses from all sectors that are looking to initiate partnership-based research projects.

PolyNat naturally participated in the 2018 and 2019 editions of the Rendez-vous Carnot, which were held successively in Lyon and Paris. This business convention organized by the Association of Carnot Institutes aims to bring together scientific players with industrial solutions and innovative companies.

The strong participation from companies proposing innovative projects and the high number of individual meetings held make the Carnot Meetings the biggest forum in France where research institutes meet industrial players. It is building a strong reputation as a place to “do business”.

2018 KEY FIGURES

Participants
2 700

94% Satisfied vistors

Business meetings
10 000

THE VISITING COMMITTEE

Each year PolyNat invites its institutional and industrial partners to give their opinions on its areas of strategic focus in the context of the “Visiting Committee”.

This event, arranged by the Strategic Coordination Committee, brings together industrial players of all sizes, competitiveness clusters, representatives from the Linksium technology transfer accelerator office in Grenoble, and delegates from the association of Carnot institutes. PolyNat presents the various actions and projects funded in the framework of its call for projects, and the committee shares its opinions and recommendations as regards the strategic positioning of the institute.

Since 2011, PolyNat has been highly committed to this annual event on account of its importance for defining and discussing the strategic directions of its research projects and keeping abreast of industrial prospects in the field of biosourced materials.

During the 2019 edition, the various stakeholders debated a topical issue: From mono-material to composite, what alternative to plastic?

THE POLYNAT DAYS

PolyNat’s 2018 and 2019 “science days” brought its teams together for two days dedicated to team-building, giving researchers, engineers, postdocs, PhD students and interns a chance to escape Grenoble for the countryside.

Each year in June, PolyNat organizes this event which aims at reviewing the projects funded and identifying areas of synergy that could be harnessed for future PolyNat projects.

The project leads present their scientific progress to the full PolyNat Scientific Committee, in order to carry out a mid-term review of ongoing projects and to assess completed projects.

Following the lakeside setting of Aix-les-Bains in 2018, the PolyNat teams met at the foot of the Hermitage hill on 26 and 27 June 2019: a place highly conducive to discussing the institute’s scientific projects and building even stronger links between the people implementing them!

THE INTERNATIONAL INDUSTRIES FORUM

As international is an integral part of its strategy, PolyNat is committed to maintaining and developing its relations with the international industrial landscape. In this sense, the **PolyNat International Industries Forum** is the key annual event of the Carnot.

The aim of the Forum is to foster constructive dialogue between PolyNat's research units and the companies in attendance, giving them the opportunity to share their perspectives and R&D challenges. The biosourced materials of the future form the common thread running through the discussions between the attendees from the various industrial sectors and the scientists from PolyNat.

In 2019, for the fifth year running, the PolyNat teams hence joined forces to attract very young businesses as well as larger national and international companies from all sectors, with a shared commitment to bringing the bioeconomy to fruition.

This edition was highlighted by the participation of the Representative of Taiwan in France, Mr François Chih-Chung WU, who has honored us with his presence at the opening of this event. During his speech, he reminded the audience of the interest of Taiwanese industrialists to participate in this international event.

The highly fruitful exchanges with companies of all sizes (from SMEs to global leaders) illustrated the huge breadth of PolyNat's partnerships and the opportunities for collaboration offered by its teams of researchers and engineers.

In addition to demonstrating the scientific synergies between the PolyNat laboratories, this event helped to strengthen the links between researchers and industrial firms working together on the materials of tomorrow!

PolyNat is proud of the success of these forums, and intends to draw on this momentum for the years to come.

THE FORUM IN FIGURES

4 days of events

36 talks in English

30 companies

2018
2019 **210** participants

Thank you to all those who attended the PolyNat International Industries Forum in 2018-2019 :

La recherche CARNOT pour l'innovation des entreprises

Carnot, research that drives industrial innovation

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AGENCE NATIONALE DE LA RECHERCHE ANR — INVESTISSEMENTS D'AVENIR

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