«Plastic» from Étienne Krähenbühl

UMR CNRS n°5223
Laboratory of Polymers Materials Engineering

IMP Lab

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Presentation of IMP

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3 Locations

200 persons

- **87 permanent staff (44 Pr and Assistant Pr, 11CNRS Scientists, 28 technical staff)**
- **113 non-permanent staff (85 Phd, 16 post-Phd, 10 contract workers)**

ORGANIZATION OF IMP

-CHEM-	-PHYSICO-	-STeRHEO-	-PHYS-
CHEMISTRY of POLYMERS	PHYSICOCHEMISTRY of POLYMERS	STRUCTURE & RHEOLOGY of POLYMERS	PHYSICAL PROPERTIES of POLYMERS

LIFE — POLYMERS AT INTERFACE FOR LIFE SCIENCES

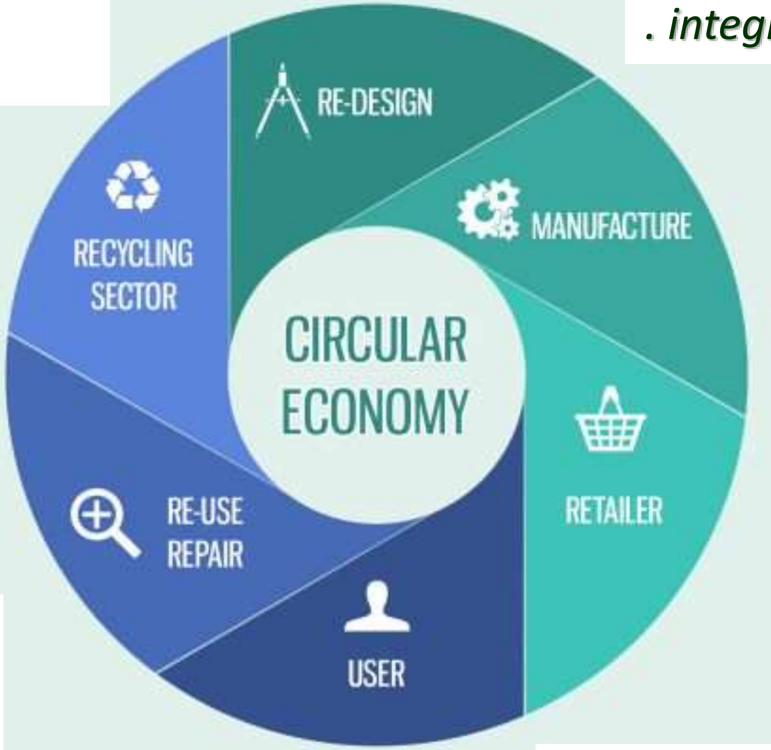
DEFI — POLYMERS FOR SUSTAINABLE DEVELOPPEMENT
With LOW ENVIRONMENTAL IMPACT

CIRCULAR ECONOMY & POLYMERS

How polymers could contribute to Circular Economy ?

Be re-usable
. in initial nature
. under other natures for other uses
(with the lowest environmental footprint)

Re-designing polymers
. using blocks from renewable resources
. integrating end-of-life stages
. integrating their life cycle analysis



Rethink their formulation and and shaping processes
. energy and material saving (without solvents)
. assembling
. allowing agility/customization

Being able to repair or self-repair
. ability to be repaired under an external stimulus
. knowing by itself to self-repair

Respond specifically to a use
. integrate a multifunctionality
. respond to external stimuli

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CIRCULAR ECONOMY & POLYMERS

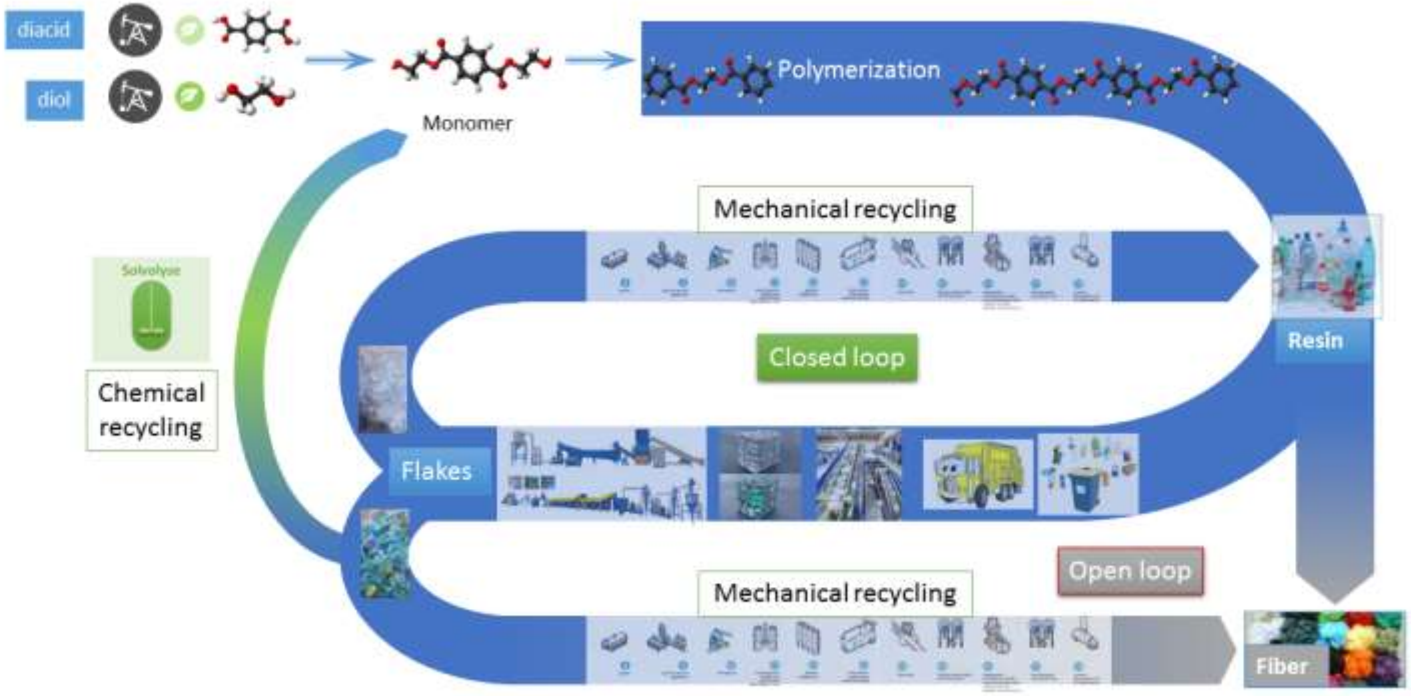
Be re-usable

. in initial nature

. under other natures for other uses (with the lowest environmental footprint)

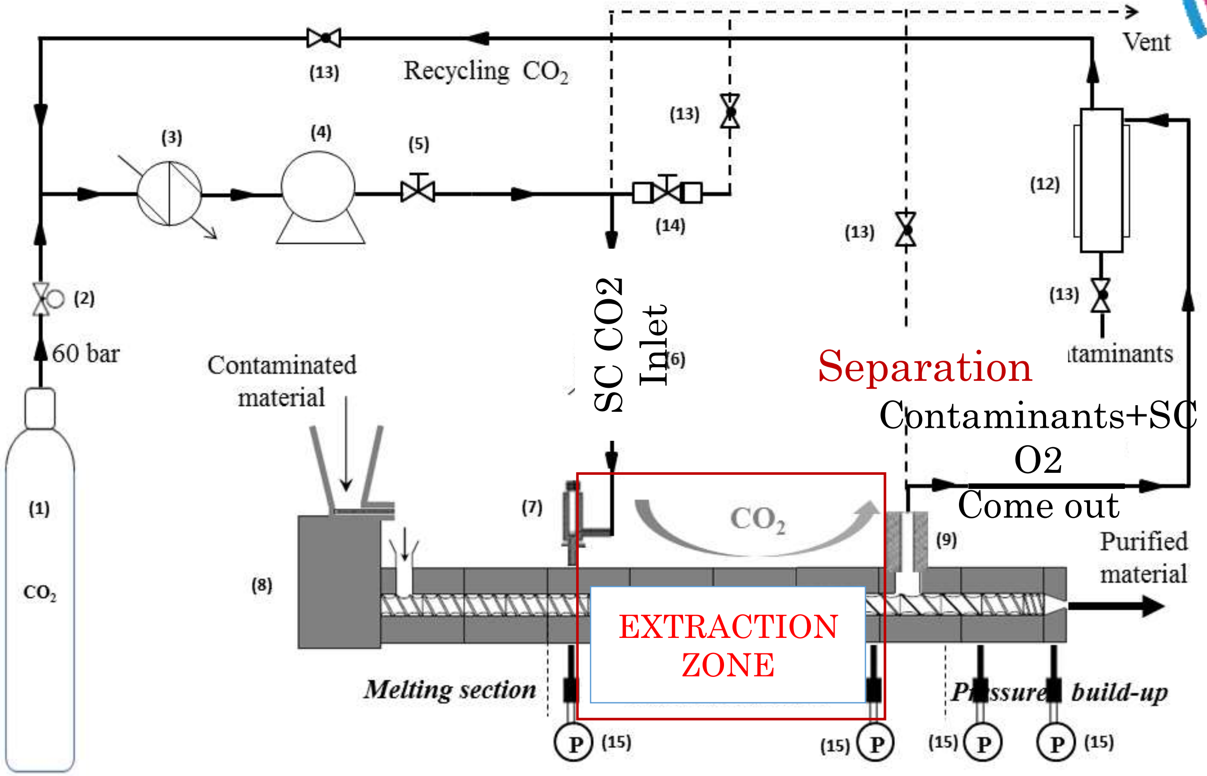
PET-related examples:

- Mechanical recycling of PET : Reactive (or not) extrusion
  Solid State Polymerization
- Chemical recycling of PET : Catalyzed depolymerization (low temperature) of polluted PET
  Preparation of high value monomers from depolymerization



Continuous decontamination by coupling the extraction during extrusion

Plateforme FlusCritEx
La plateforme qui associe les fluides supercritiques et l'extrusion de polymères pour une réponse multisectorielle



Twin screw extrusion

Benefits

- ✓ Continuous process offering one-step extraction and granulation
- ✓ Extraction of molecules up to 400 g/mol
- ✓ More efficient than thermal desorption or steam distillation processes,

CIRCULAR ECONOMY & POLYMERS

Redesigning polymers

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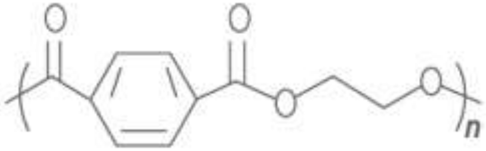
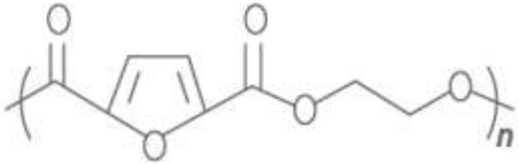
PET-related example:

- **Substitution by PEF**
  Polymerization of FDA
- **Use of biosourced monomers**
  Isosorbide, furanic acid, etc
- **Design of PET-like biosourced materials**
  Physical properties
  Processing as films, fibers

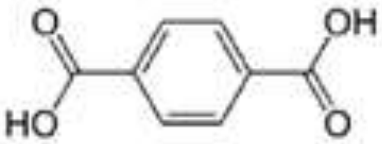


Polyethylene terephthalate (**PET**)



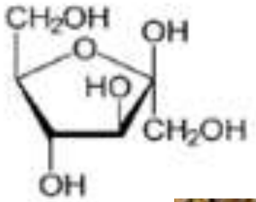
Polyethylene Furanoate

Monomer: terephtalic acid

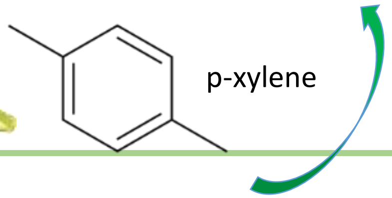


Monomer: furandicarboxylic acid

Fructose



Monomer: terephtalic acid



CIRCULAR ECONOMY & POLYMERS

Redesigning polymers

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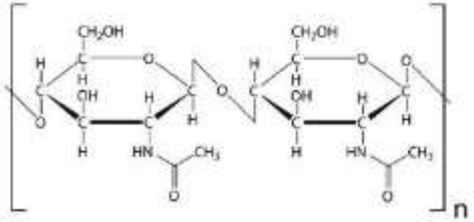
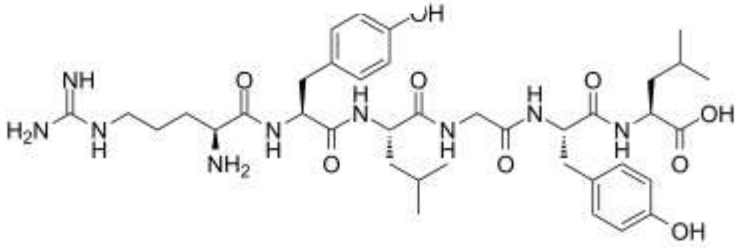


Natural polymers based materials (biopolymers)

- Polysaccharide-based materials :
  - Cellulose, guar gum, etc
  - Chitine/chitosane



- Use of proteins as bases for materials series
  - Casein: Extrusion of films, injection of parts
  - Artificial leather from food wastes

Additives substitutions using biosourced components

Essential oils, natural insect repellants, natural antioxydants from biomass

Design, formulation, and processing of environmentally friendly polymers (Safe and Sustainable by Design)

Non-isocyanate polyurethanes including bio-based NIPUs

Bio-based (and biosourced) polyesters (saturated and unsaturated)

Bio-based epoxies for substitution of bisphenol-A based ones: isosorbide, vanilin, tannins, etc

Bio-based phenolics for adhesives, structural composites

CIRCULAR ECONOMY & POLYMERS

Rethink their formulation and shaping processes

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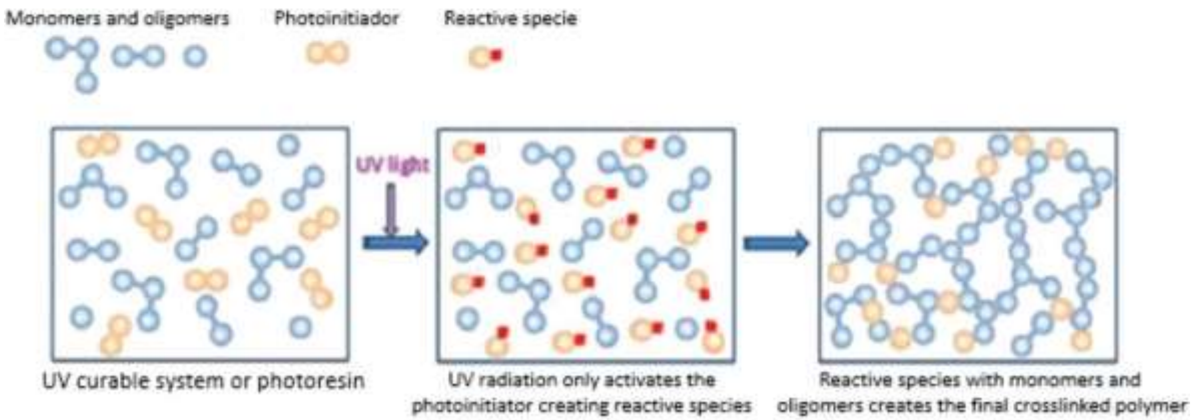
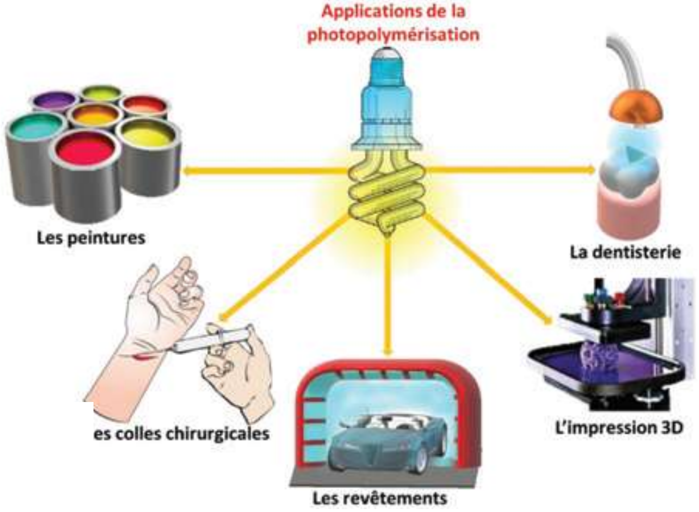
. assembling

. allowing agility/customization

Examples

- **Photopolymerization: low energy consumption, short time reaction, 3D printing**



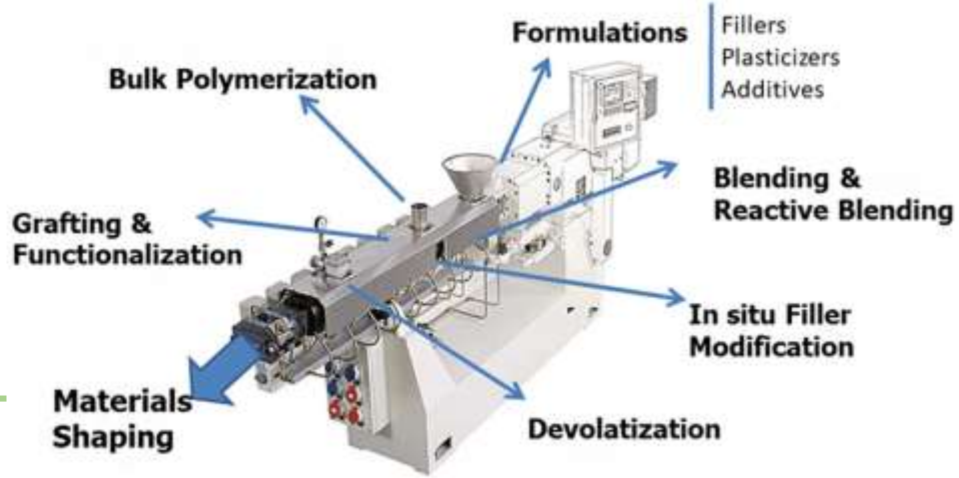


- **Reactive extrusion:**

  No solvent use

  Short time of reaction

. Synthesis of various polymers: PLA, PCL, PU, etc



CIRCULAR ECONOMY & POLYMERS

Being able to repair or self-repair

. ability to be repaired under an external stimulus

. knowing by itself to self-repair

Supramolecular chemistry for polymers

- Introduction of supramolecular units to introduce reversible bonds (physical bonds: H, chelation) versatile processing
  - . thermoplastics (ionomers)
  - . crosslinked polymers:

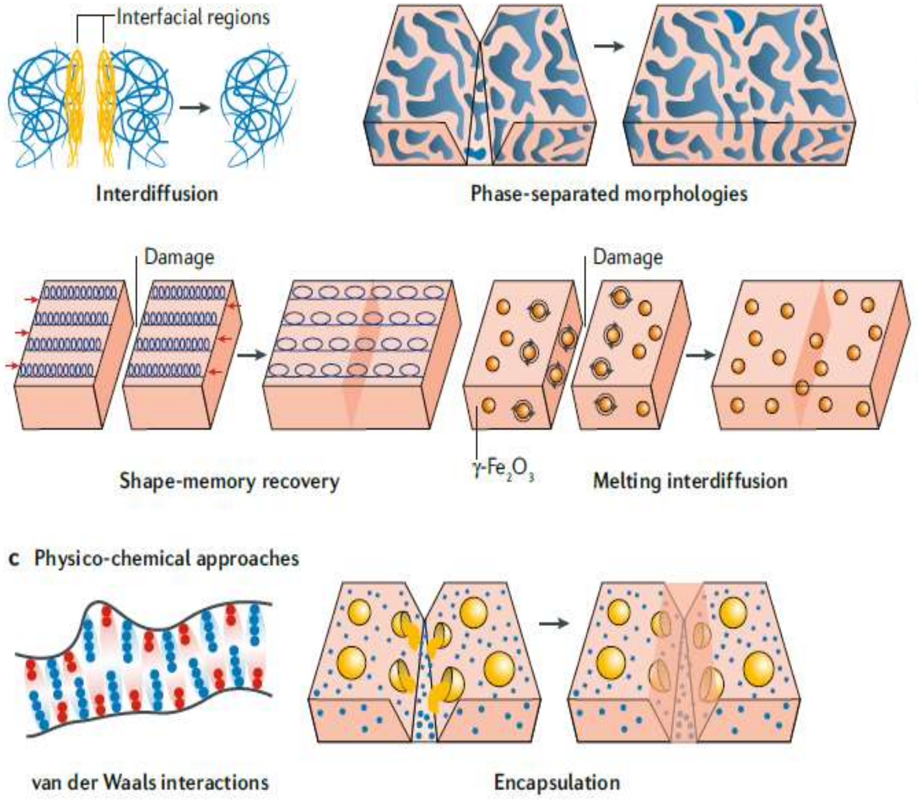
Vitrimers = Thermosets processable as thermoplastics

⇩

Recycling and re-use ↗

Healing of polymer damages (repair/re-use – durability)

- Introduction of mandable bonds (at moderate temperature)
  Diels-Alder chemistry for matrices and interfaces
- Modification of polymers for self-healing ability
  Polymer blends
  Breakable microcapsules containing healing agent



adapted fromS. Wang et al. Nature Rev. Mater., 2020

CIRCULAR ECONOMY & POLYMERS

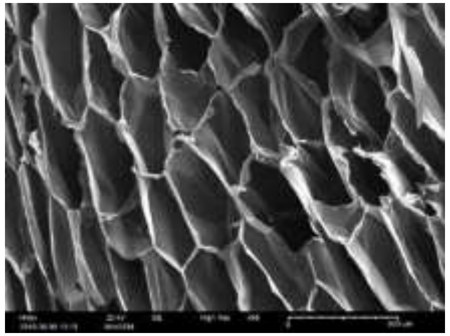
Respond specifically to a use

. integrate a multifunctionality

. respond to external stimuli

Allowing to reduce the use step environmental footprint

- Lightweigth polymer materials using solvent-free methods such as supercritical CO_2, biofoams (PUR)
- Aerogels for thermal insulation
- Design of thermoplastic matrix-based composite materials: recovering of both TP matrix and fibers (improved recycling of structural composite materials)



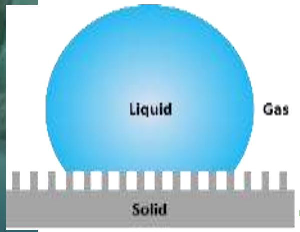
Integration of several functionalities in a single polymer material instead of combining several polymers, i.e. solving the generated problems of reycling (collecting, sorting, cross contaminations, etc)

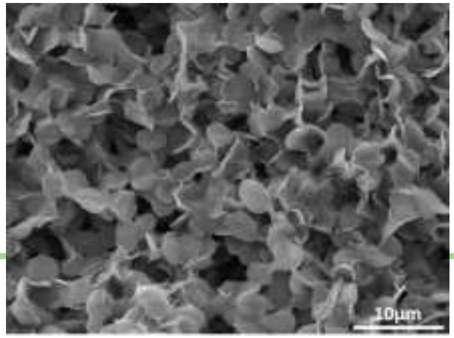
Packaging films based on a single layer instead of multilayers

gas barrier (CO_2, H_2O, O_2) + mechanical properties + printability + … (incl. biodegradability)

Eco-design of flexible printed electronics

Superhydrophobic surfaces of conventional plastics without additional surface treatments: recycling issues





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CIRCULAR ECONOMY & POLYMERS

CNRS PRIME TEAM 'BIOLOOP'

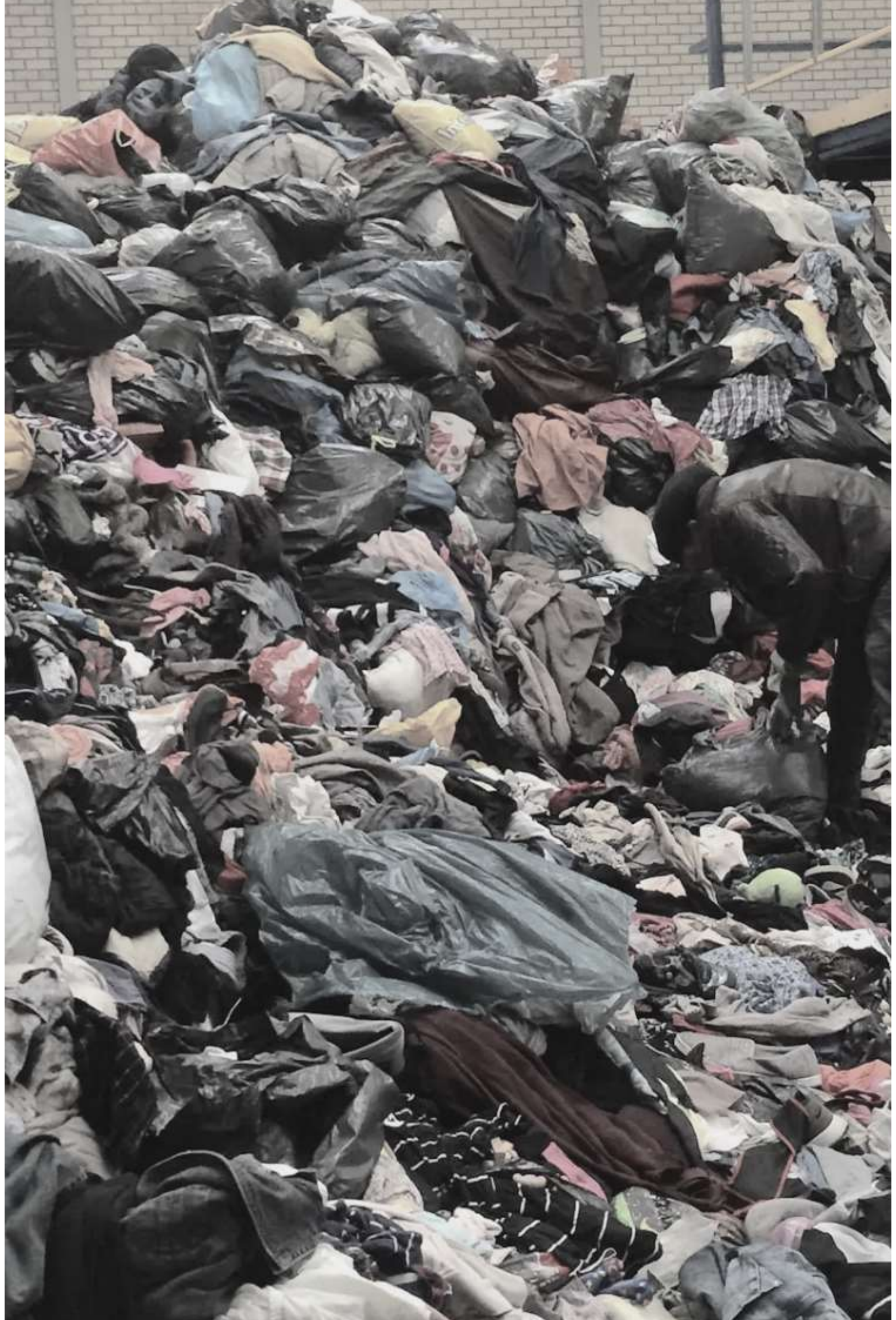
Dr Olivier Brette

Dr CNRS Nathalie Lazaric

interdisciplinary team on bioplastics, recycling, recyclability, LCA, economics, politics shared with two other UMRs GREDEG & TRIANGLE

Chair Pr Dr Sylvestre NJAKOU
On Circular Economy

Dr Valérie Massardier



LANCEMENT PROJET PEPR VLAN TEXTILES
18/09/2023 ROUBAIX

Valorisation et Recyclabilité des Déchets Textiles

Duchet-Rumeau, J.; Livi, S.; Nachbar, M.

UNIVERSITÉ DE LYON
imp Ingénierie des Matériaux Polymères
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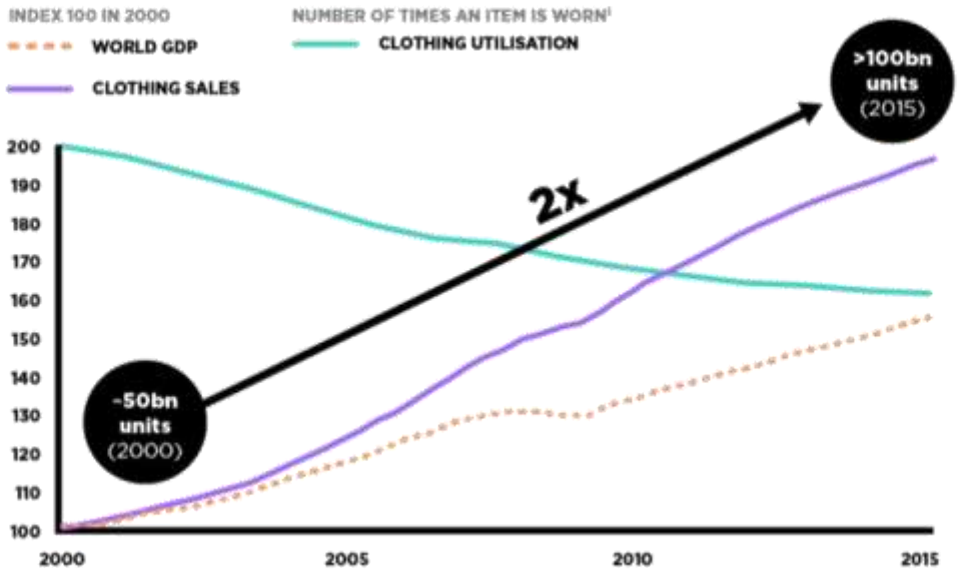
Industrie Textile

Production mondiale des fibres textiles

2000 — 58 millions de tonnes

2020 — 109 millions de tonnes

2030 — 145 millions de tonnes



Fast Fashion

Impacts environnementaux

73% de déchets textiles sont mis en décharge ou incinérés

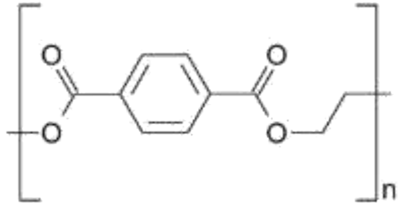
10% des émissions de gaz à effet de serre

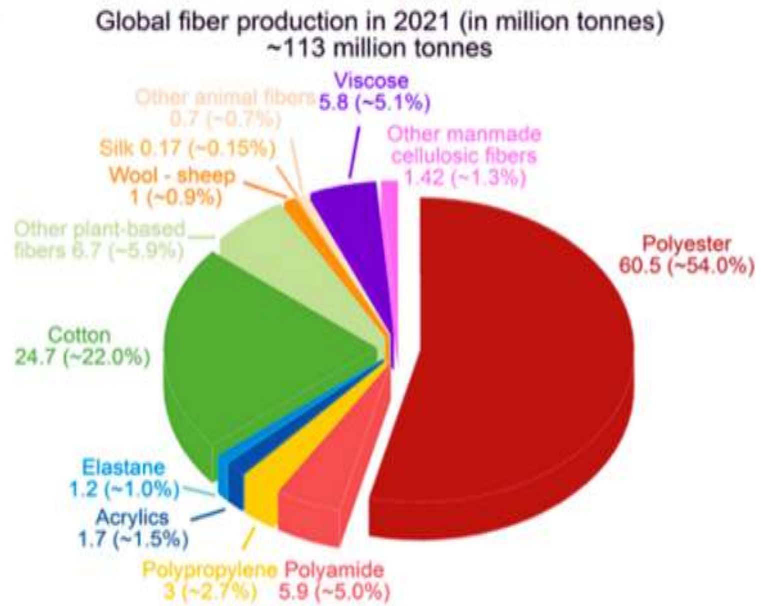
2700 litres d'eau pour 1 t-shirt en coton

0.5 millions de microfibres rejetées dans l'océan

Ellen MacArthur Foundation

Les Fibres Textiles - Polyester (PET)





L’une des fibres la plus importante

- 60% de la production de PET est destinée au secteur textile
- Bas prix de production
- Bonnes propriétés mécaniques et physico-chimiques

Recyclabilité des Fibres Textiles

- Difficulté de collecte/ tri vêtements
- Fibres multi composants (mélanges PET-Cotton)
- Présence d’additifs (par exemple les pigments des vêtements)
- Qualité de fibres en fin de vie (usure par lavage, longueur des fibres)
- Masse molaire et “melt strength“
- La plupart des technologies se limitent au “downcycling”

RECYCLING & UPCYCLING Fibres PET

Par une approche MATERIAL BY DESIGN

RECYCLAGE DES FIBRES PET	Eco-DESIGN DU PET	Eco-DESIGN DU PET	Eco-DESIGN DU PLA
Explorer le recyclage chimique des fibres PET avec des liquides ioniques et les solvants “deep eutectics”.	Déclencher le recyclage chimique des fibres PET sous stimulus avec des liquides ioniques et les solvants “deep eutectics”encapsulés.	Elaboration de systèmes vitrimères à partir de déchets textiles basés sur la transestérification des composants biosourcés/ verts.	Formulation du PLA Pour l’obtention de performances, rhéologiques et mécaniques pour la recyclabilité du polymère
Valorisation des Monomères	**Prévoir ou prolonger la fin de vie du PET**	**Développement de Vitrimères**	**Développement de PLA performants et recyclables**

RECYCLING & UPCYCLING Fibres PET

Par une approche MATERIAL BY DESIGN

RECYCLAGE DES FIBRES PET	Eco-DESIGN DU PET	Eco-DESIGN DU PET	Eco-DESIGN DU PLA
Valorisation des Monomères	**Prévoir ou prolonger la fin de vie du PET**	**Développement de Vitrimères**	**Développement de PLA performants et recyclables**

APTITUDE AU FILAGE

Analyse du Cycle de Vie

Thank you for your attention

And follow ***IMP lab*** on *X*

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