

BIO-BASED SUSTAINABLE PLASTIC MATERIALS

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« *Plastics make our lives more convenient...* »





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Celluloid, John Wesley Hyatt (1869)





« *Plastics make our lives more convenient...* »

Inexpensive



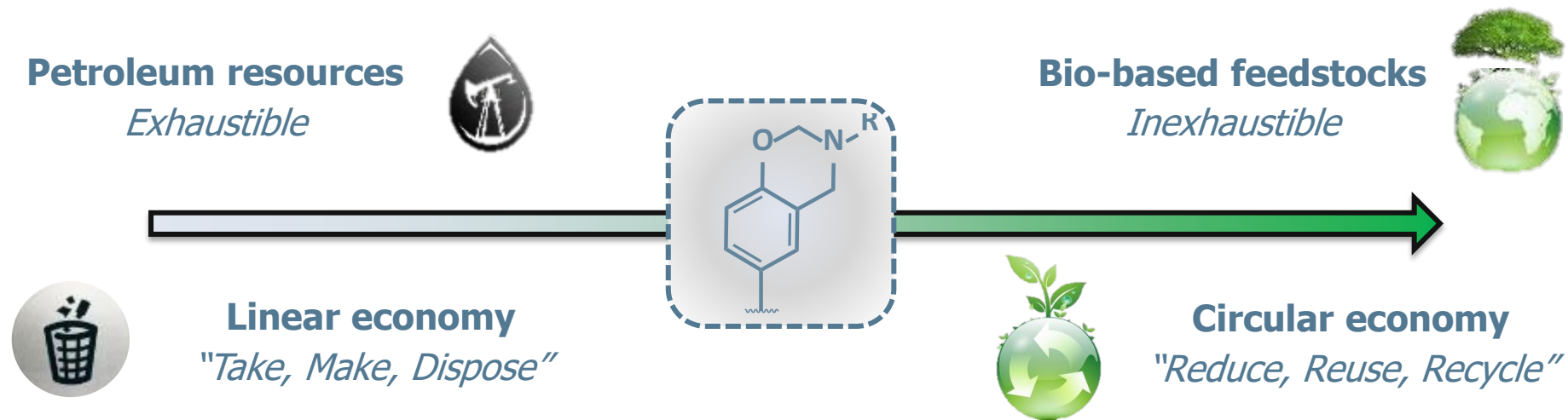
Moldable



Lightweight

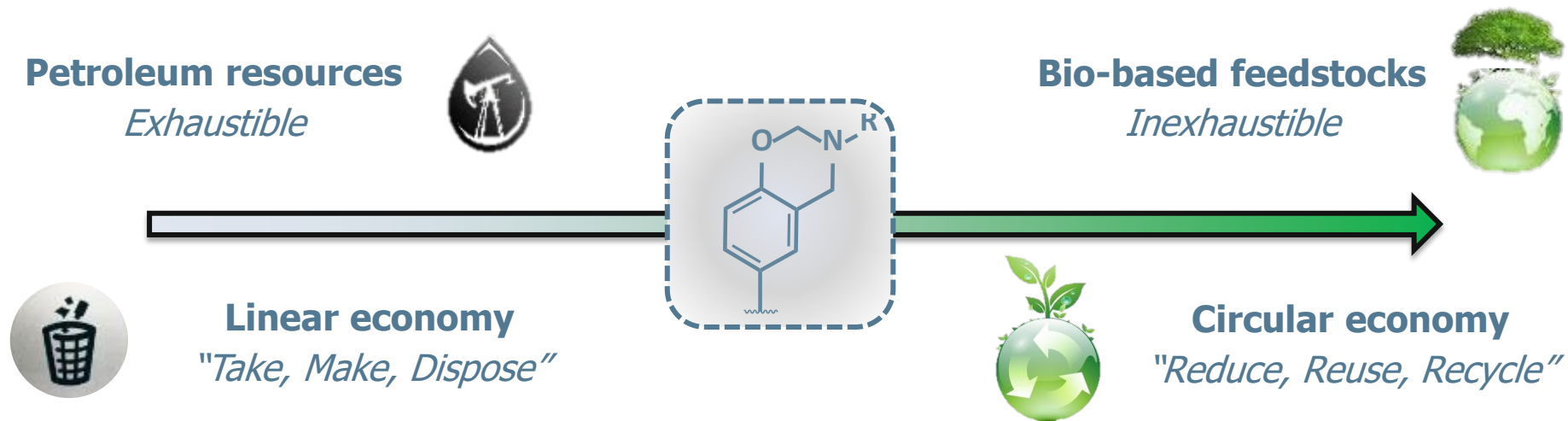


...but they are a major cause of environmental pollution."





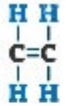
...but they are a major cause of environmental pollution."



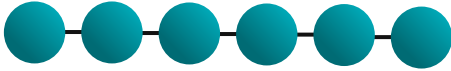
Sustainable-by-design approach

All plastics are polymers...

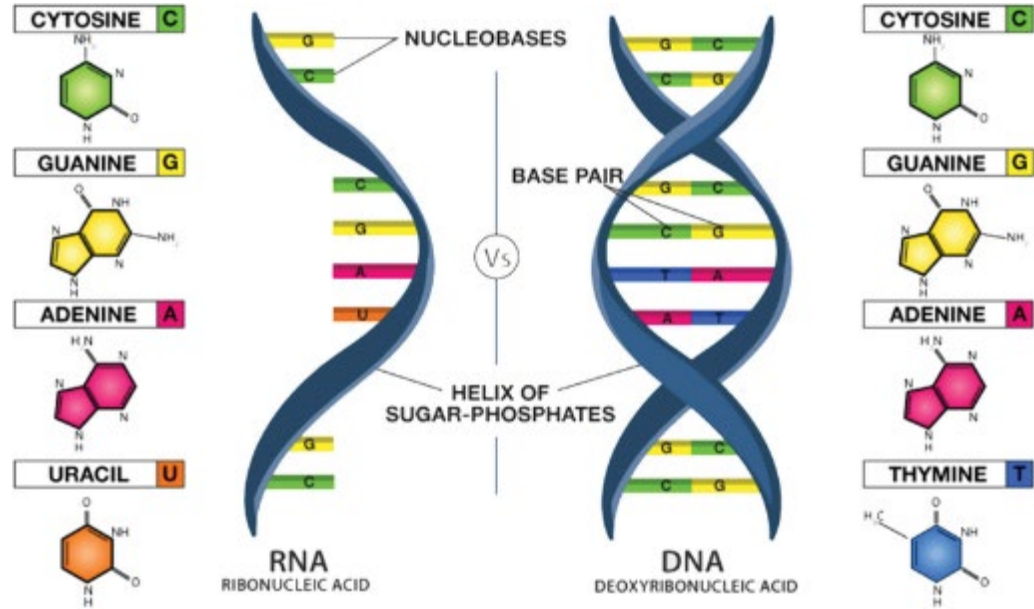
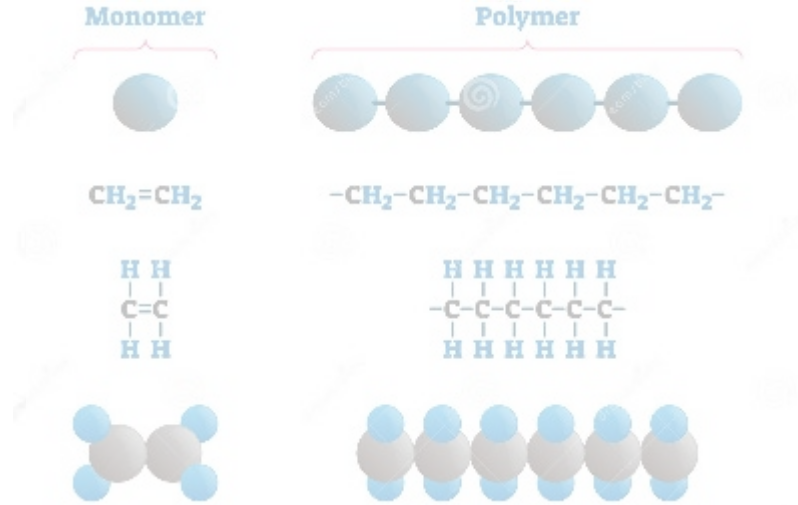
Monomer



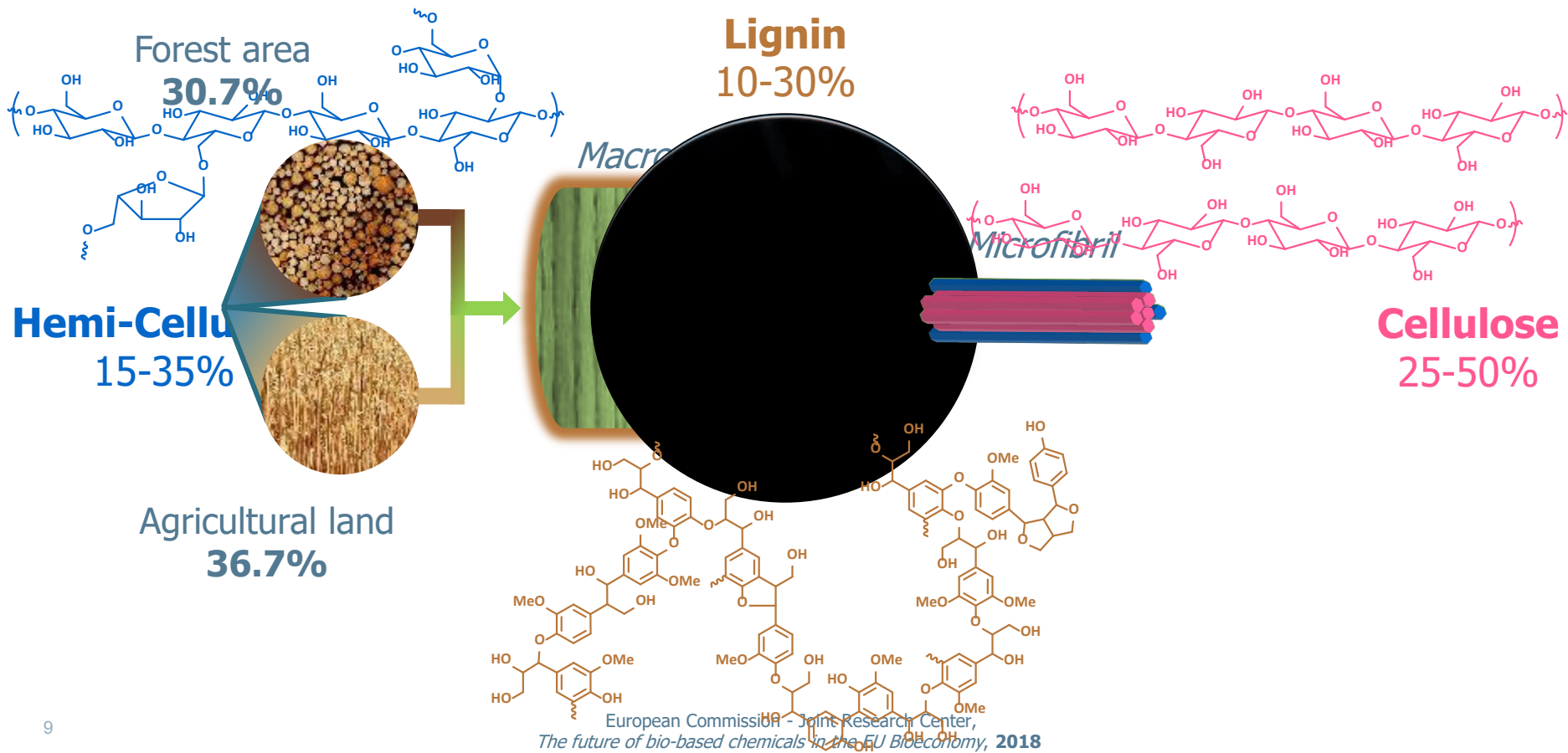
Polymer



... but not all polymers are plastic!



Lignin : a renewable feedstock for polymers

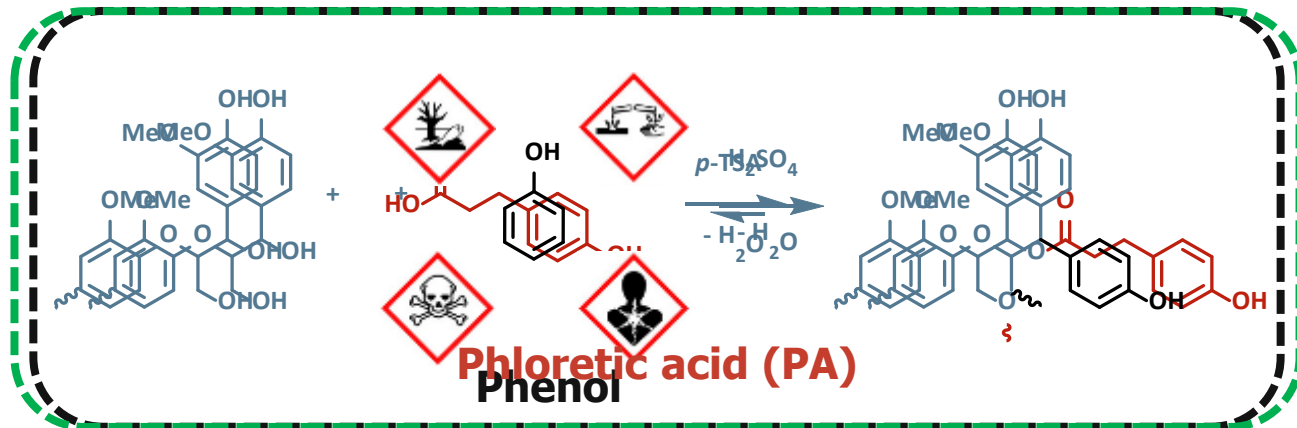


Application of the Green Chemistry principles

Alternative route: Sustainable esterification

Less Hazardous
Chemical
Syntheses

Safer Solvents
and Auxiliaries



Use of Renewable
Feedstocks

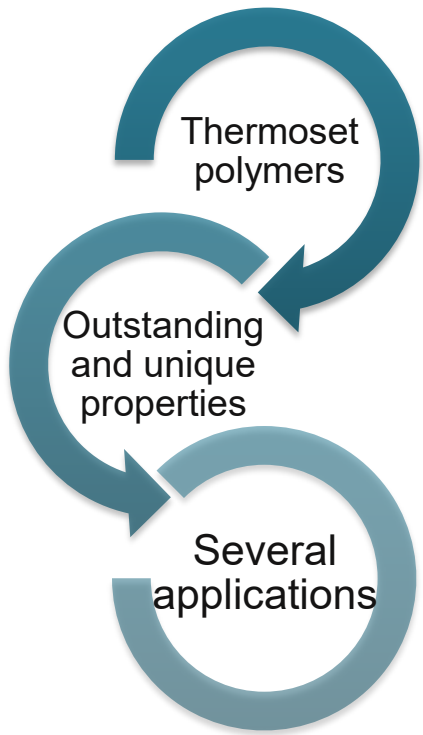
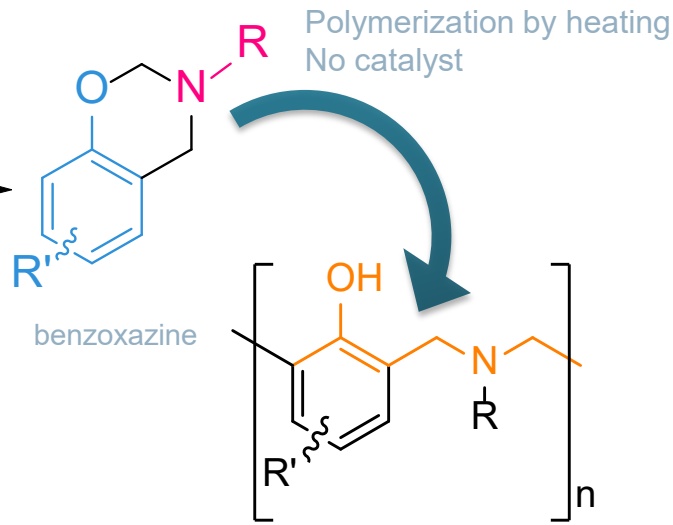
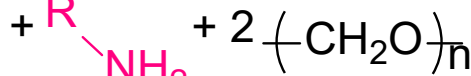
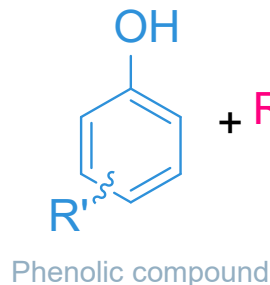
Designing Safer
Chemicals

12 Principles
of Green Chemistry



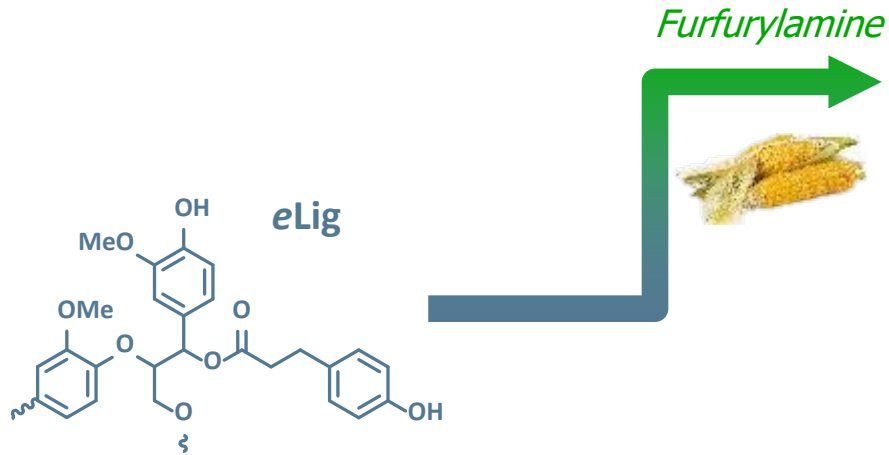
Benzoxazines

- Monocomponents
- High glass transition temperature (up to 300°C)
- High thermal stability (up to 400°C)
- Low release of by-products during polymerization
- Excellent fire properties

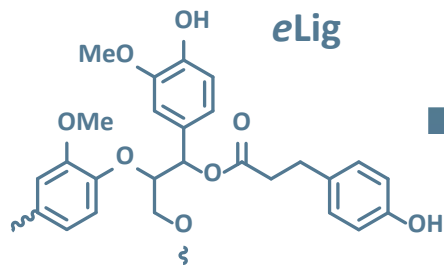




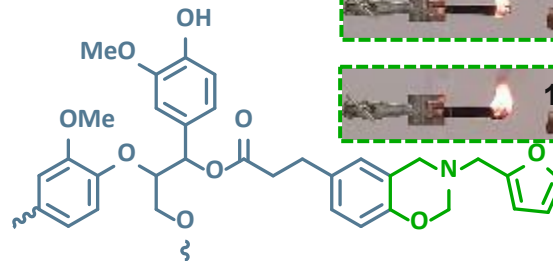
Synthesis of lignin-based benzoxazines



Synthesis of lignin-based benzoxazines



Furfurylamine



15s



5s



18s

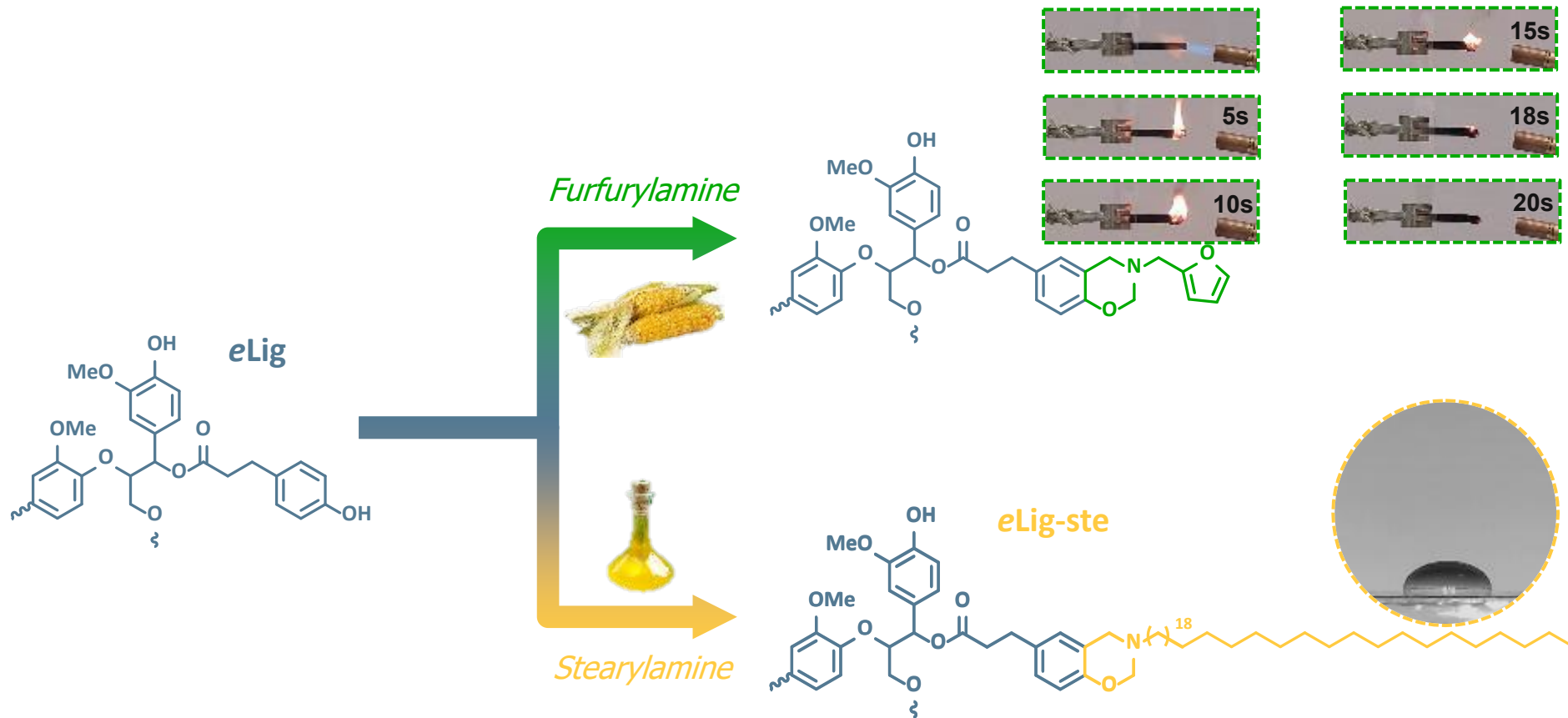


10s



20s

Synthesis of lignin-based benzoxazines

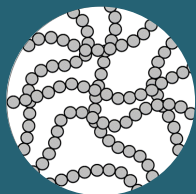


What about "unrecyclable" plastics?



Vitrimers, a new class of polymers

Thermoplastic



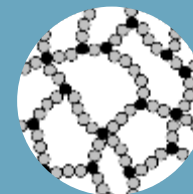
- Chemically independent
- Easy to reshape and to remodel
- Sensitive to solvent

Vitrimer



- Recycling and reprocessing properties of thermoplastics
- Mechanical properties of cross-linked thermosets

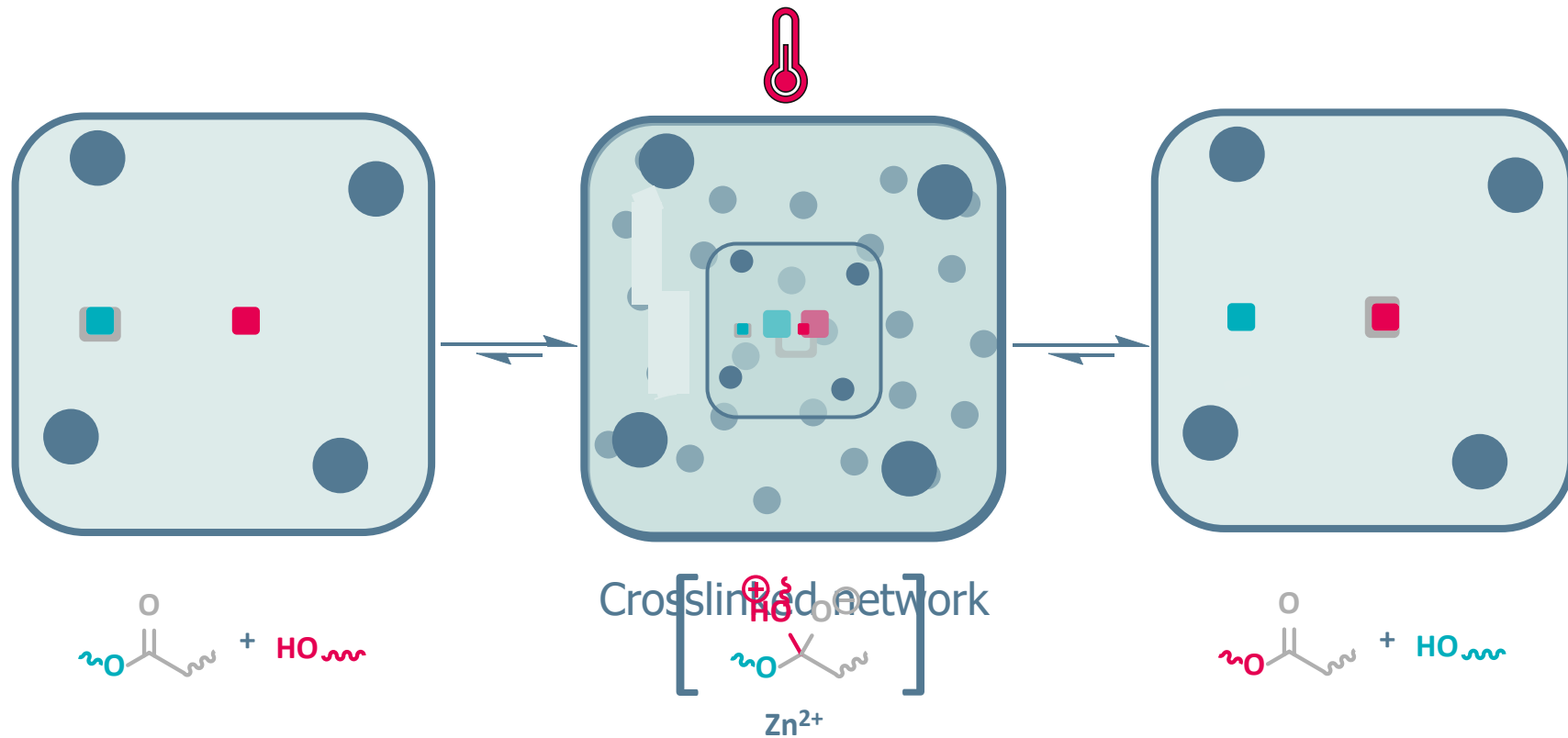
Thermoset



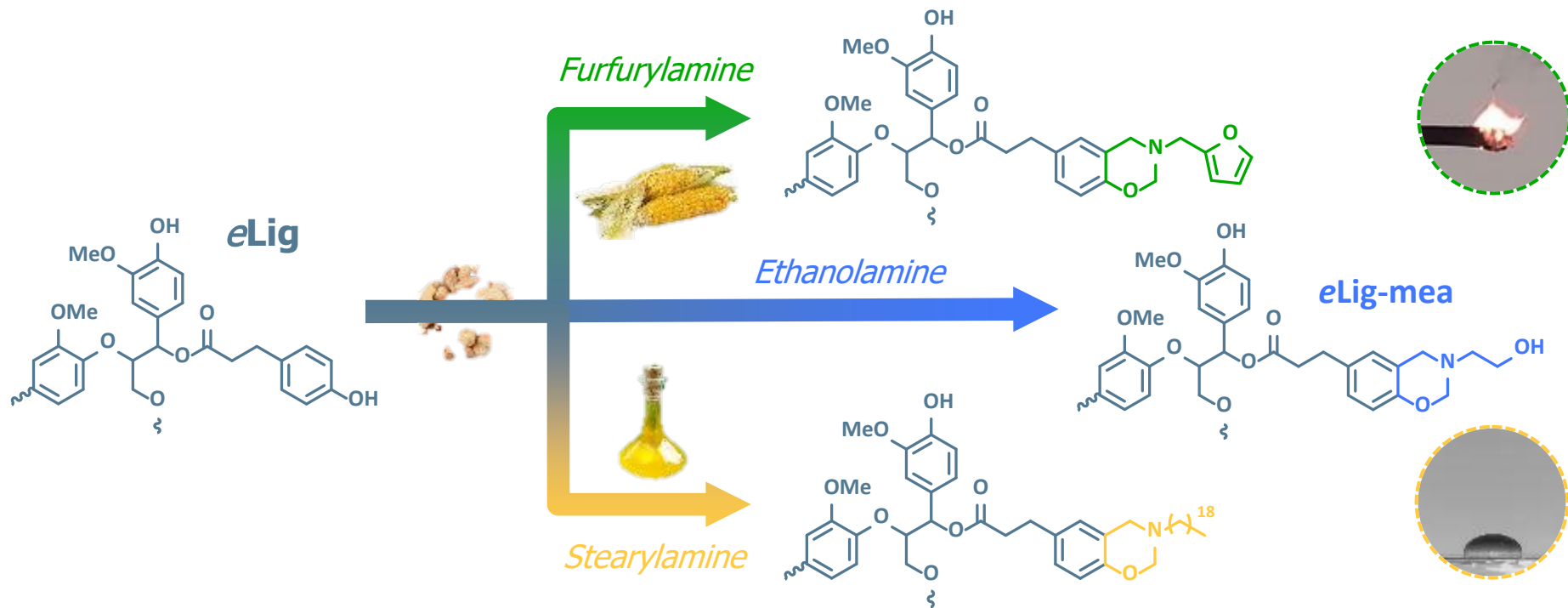
- Chemically cross-linked
- Permanent shape
- Higher mechanical, thermal, and solvent resistance



Transesterification: a dynamic exchange

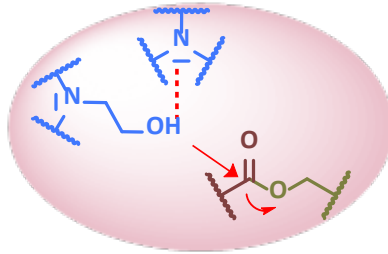


Synthesis of lignin-based benzoxazines





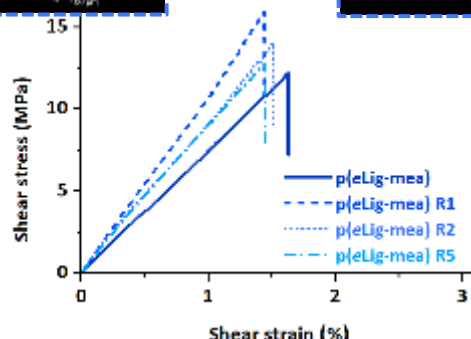
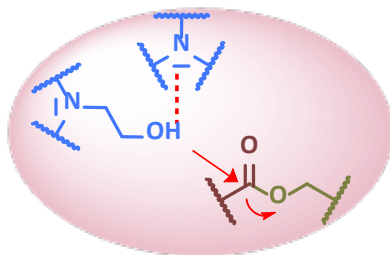
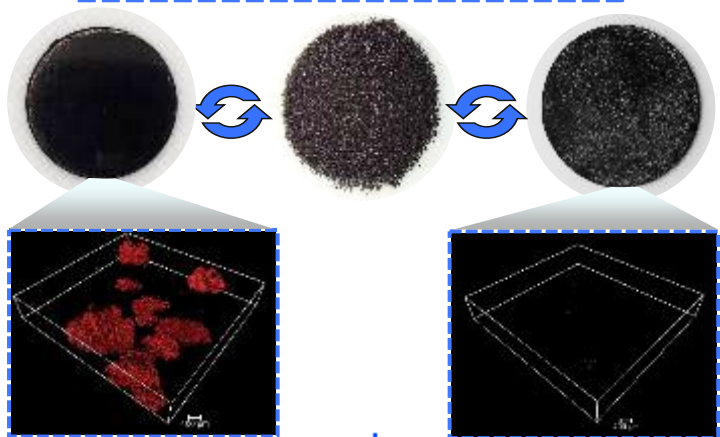
Recyclable lignin-based vitrimers



- *Transesterification dynamic exchanges*
- *Internally catalyzed by N*
- *Benefiting from a neighboring group participation effect*

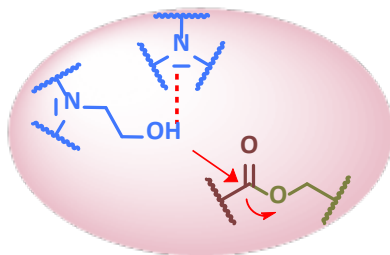
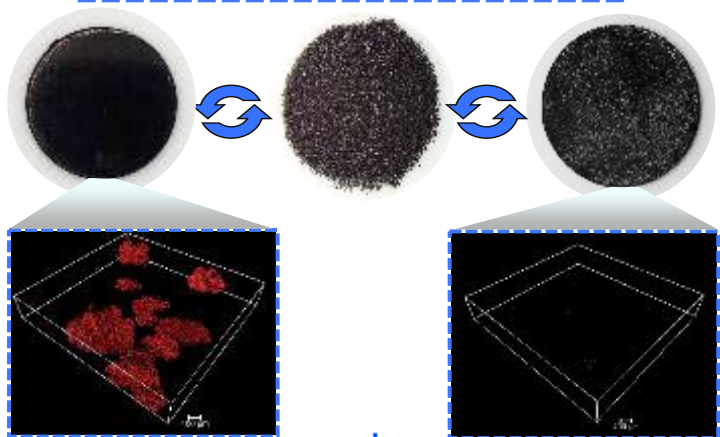
Recyclable lignin-based vitrimers

Mechanical recycling



Recyclable lignin-based vitrimers

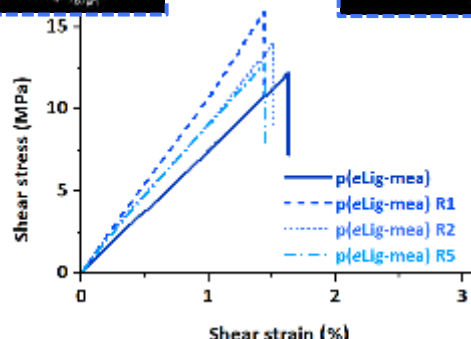
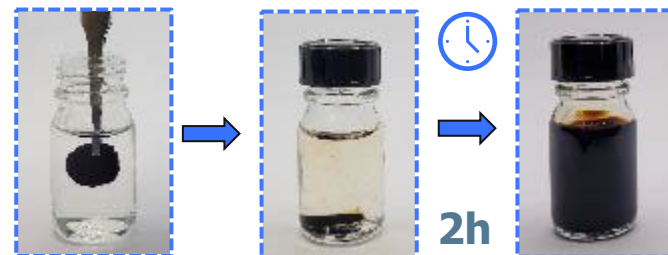
Mechanical recycling



NaOH

T_{amb}

Degradability





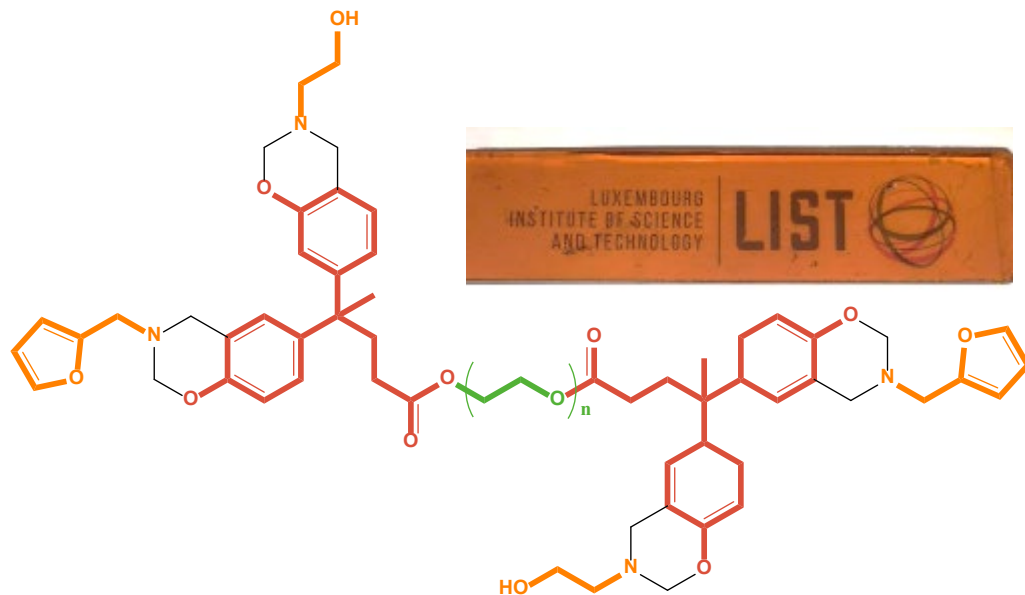
Other benzoxazine-based vitrimers

PEG-based benzoxazine vitrimers



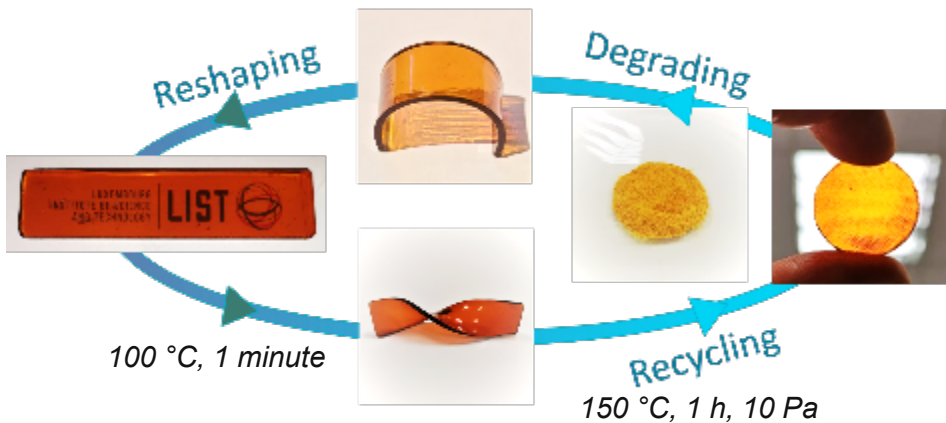
Other benzoxazine-based vitrimers

PEG-based benzoxazine vitrimers



Other benzoxazine-based vitrimers

PEG-based benzoxazine vitrimers

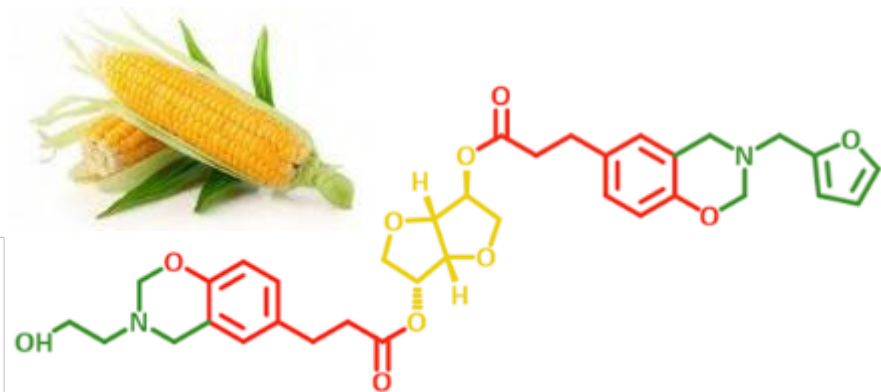


Self-healing (pressure free), 140 °C



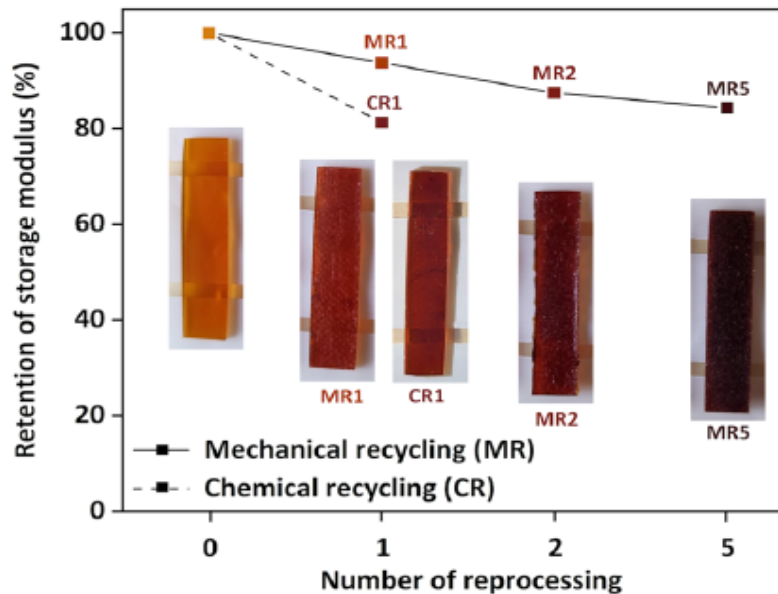
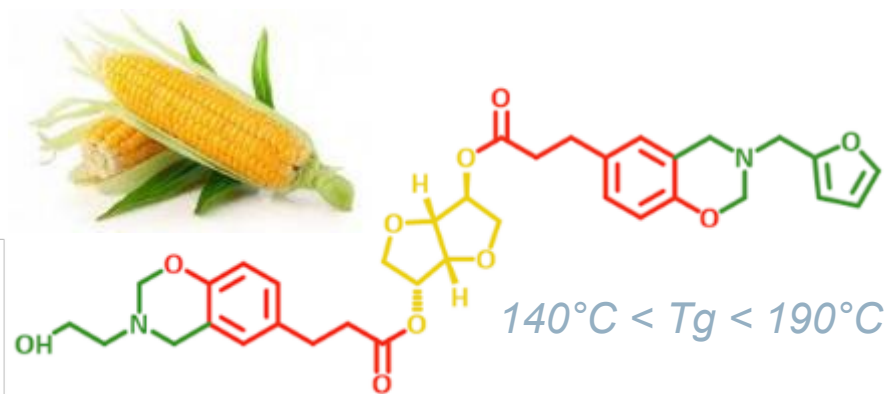
Other benzoxazine-based vitrimers

Isosorbide-based benzoxazine vitrimers



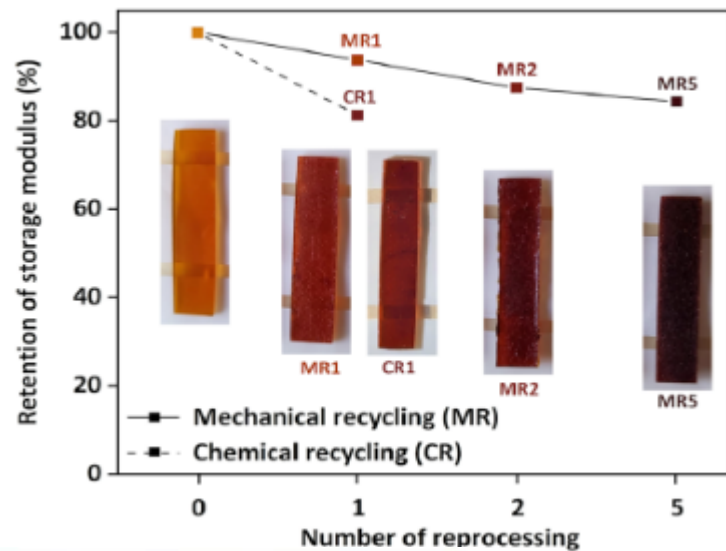
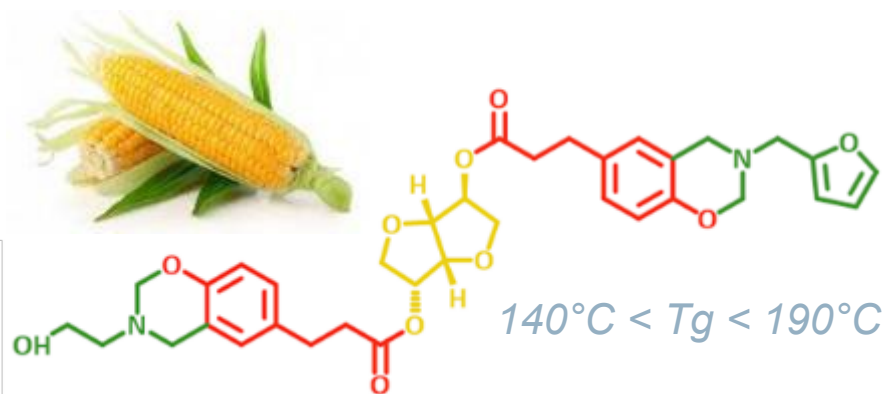
Other benzoxazine-based vitrimers

Isosorbide-based benzoxazine vitrimers

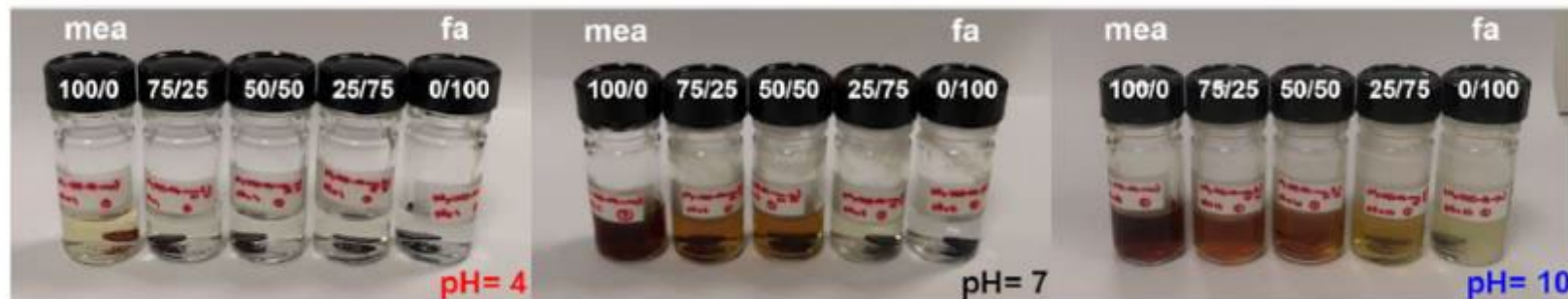


Other benzoxazine-based vitrimers

Isosorbide-based benzoxazine vitrimers



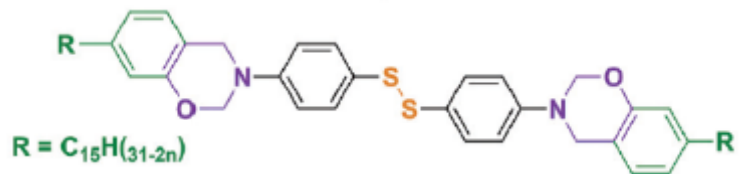
Degradation test, buffer solution (20 days, 80 °C)





Other benzoxazine-based vitrimers

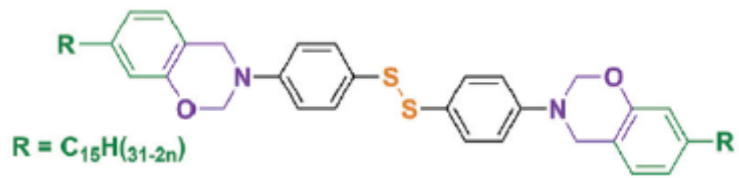
Cardanol-based benzoxazine vitrimers



kg scale

Other benzoxazine-based vitrimers

Cardanol-based benzoxazine vitrimers



kg scale



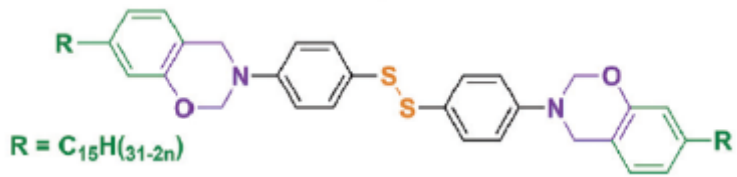
Solid state vitrimeric tape



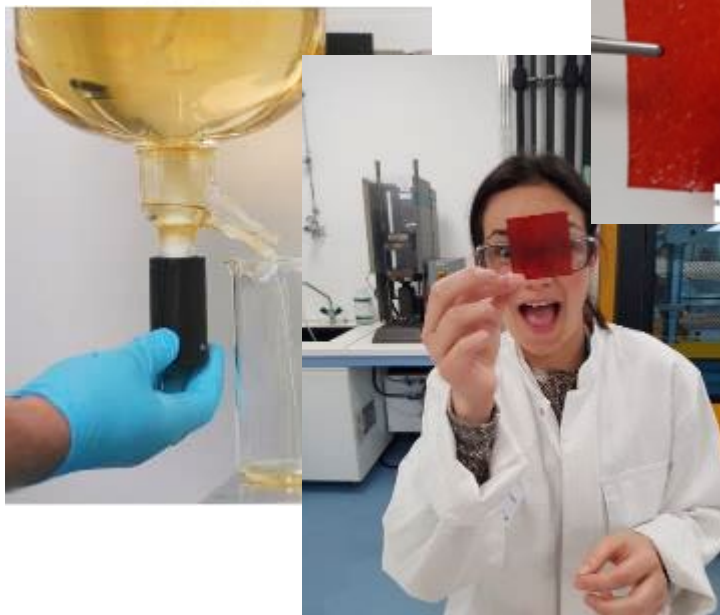


Other benzoxazine-based vitrimers

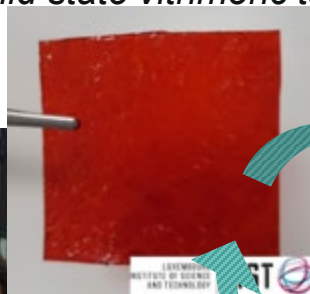
Cardanol-based benzoxazine vitrimers



kg scale



Solid state vitrimeric tape



120 °C, 8 bar

120 °C, 8 bar



8 MPa

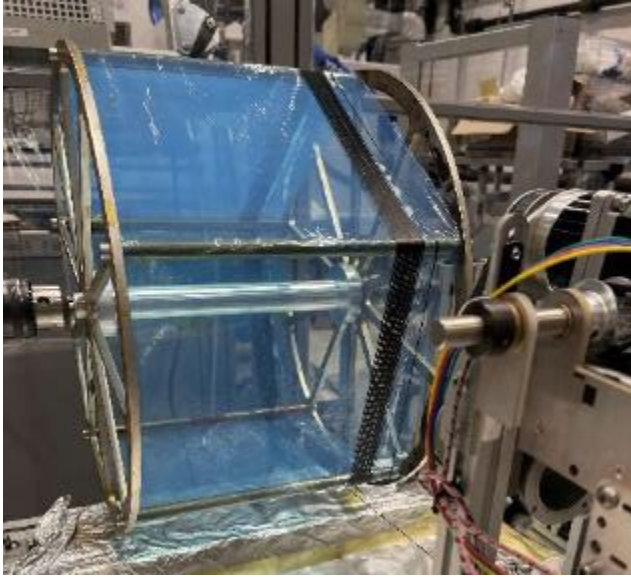
120 °C, 8 bar

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Benzoxazine-based vitrimers composites

Tape manufacturing by filament impregnation



UD tapes after filament winding and solvent drying



- *Reference resin (does not meet yet mechanical specifications)*
- *Degassed resin + 15% 2-MeTHF*
- *Impregnation temperature: 50°C*
- *4 tr/min*
- *Nozzle in: 1.0mm*
- *Nozzle out: 1.1mm*

Benzoxazine-based vitrimers composites

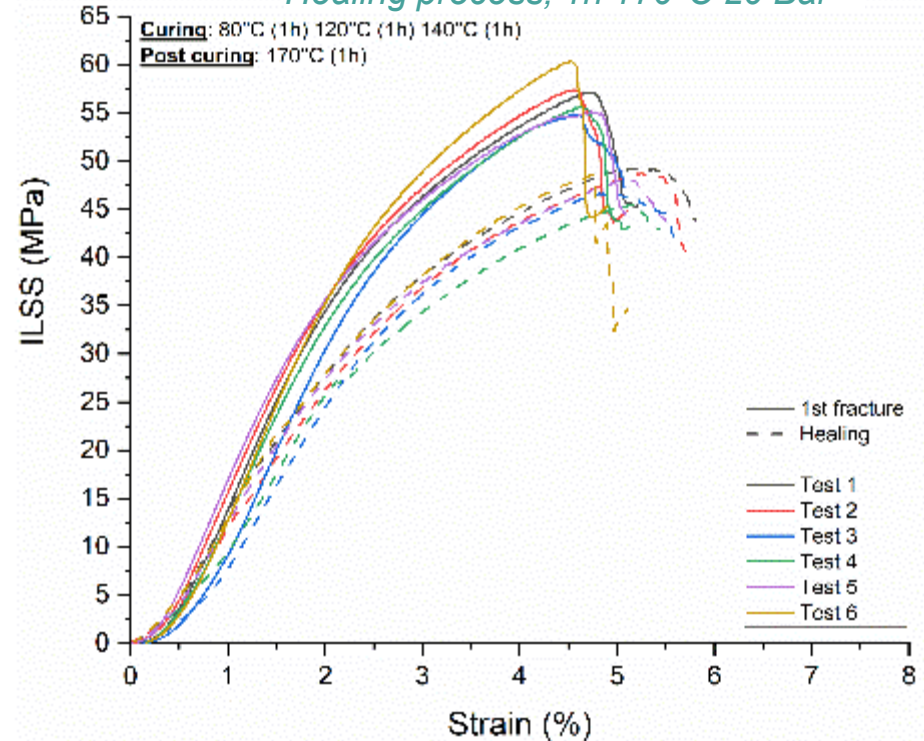
Composites and self-healing

SEM analyses

MV mag pressure WD det spot 100 µm
15.00 kV 1 000 x 00 Pa 10.0 mm/BSED 4.5 LST

- Reference resin (does not meet yet mechanical specifications)
- Degassed resin + 15% 2-MeTHF
- Curing cycle : 1h 50°C, 1h 80°C, 1h 120°C, 1h 140°C, 1h 170°C

Self-healing after ILSS testing
Healing process; 1h 170°C 20 Bar



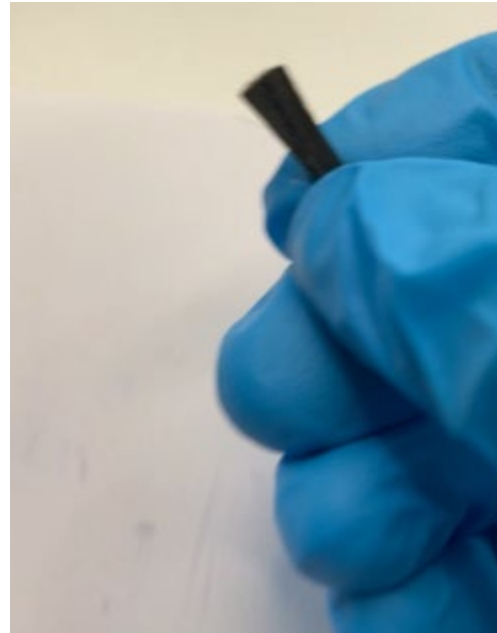
Benzoxazine-based vitrimers composites

Chemical recycling by acidolysis



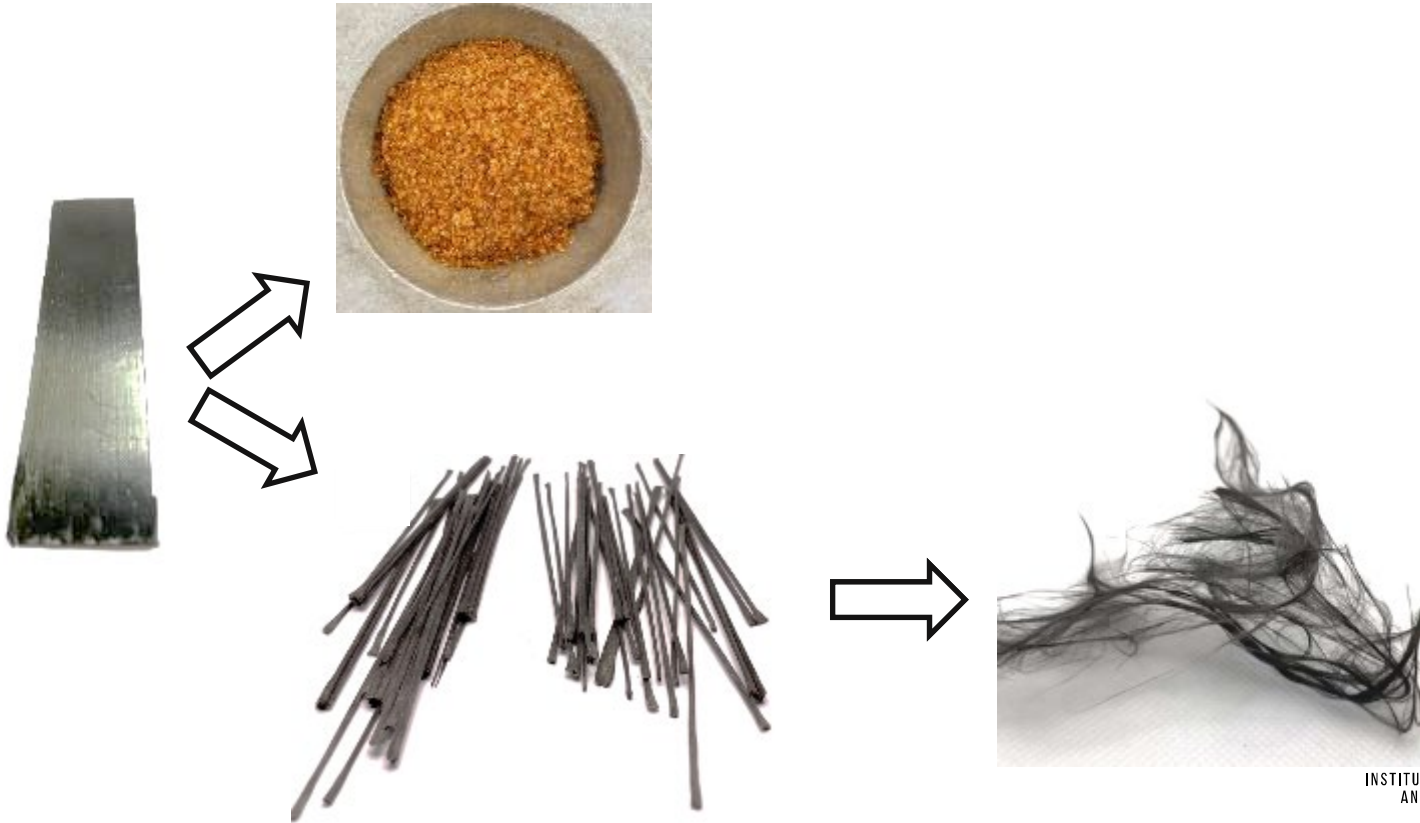
Benzoxazine-based vitrimers composites

Chemical recycling by acidolysis

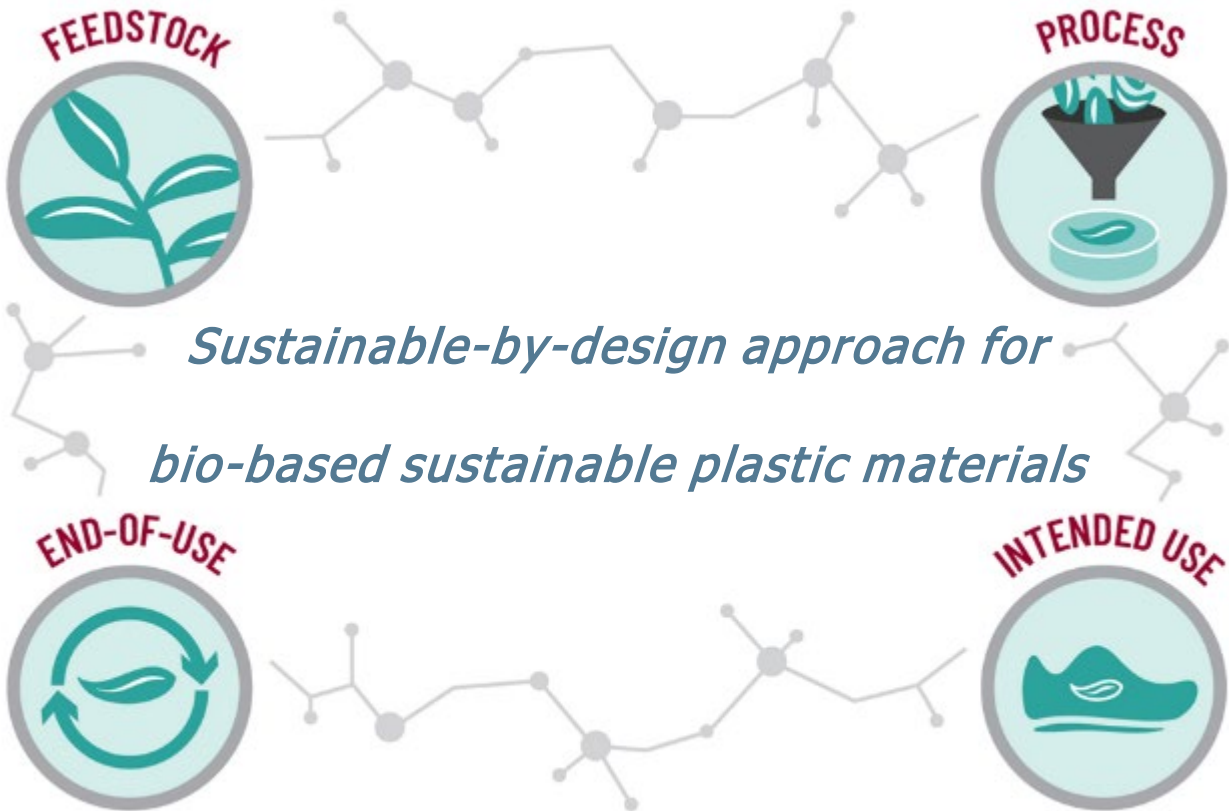


Benzoxazine-based vitrimers composites

Chemical recycling by acidolysis



Conclusions





GREENSHAPeR: B21/MS/16721229
LIGNOBENZ : C18/MS/12538602
SUSPOCO : P22/MS/14.305.244
VITRISPACE



WHERE TOMORROW BEGINS

LIST.lu



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