Sustainable polymers

Institute of Chemical Research of Catalonia (ICIQ)

Prof. Emilio Palomares

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Institut Català d'Investigació Química

01.

The Institute of Chemical Research of Catalonia (ICIQ)

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ICIQ 2024 en xifres

Recerca i impacte

19 Grups de recerca

- Catàlisi sostenible
- Energies renovables
- Medicina molecular

Experimental

Computacional

148 publicacions científiques » **142** articles i revisions

66% col·laboracions internacionals

3,8 Impacte normalitzat (ESI Química)*

*març 2025

7 ERC en curs

Advanced Grant

Prof. Antonio M. Echavarren

Prof. Emilio Palomares

Prof. Ruben Martin

Consolidator Grant

Prof. Marcos Garcia Suero

Proof of Concept Grant

Prof. Marcos Garcia Suero

Starting Grant

Dr. Elisabet Romero

Dr. José A. Berrocal

Prof. Katherine Villa

9 Professors/es ICREA

Prof. Pau Ballester

Prof. Julio Lloret-Fillol

Prof. Jordi Burés

Prof. Ruben Martin

Prof. J.R. Galán-Mascarós

Prof. Emilio Palomares

Prof. Marcos Garcia Suero

Prof. Beatriz Prieto-Simón

Prof. Arjan W. Kleij

Persones

Un conjunt de persones compromeses que treballen de manera col·laborativa per aconseguir objectius comuns i ampliar els horitzons del coneixement.

42% internacional

325 Persones treballadores (EJC)

	DONES	HOMES
Investigadors/es postdoctorals	20	48
Coordinadores científiques de grup	4 dones	
Investigadors/es predoctorals	37	64
Estudiants de màster	6	8
Tècnics/es de laboratori grups de recerca	4	8
Àrea de suport a la recerca	14	12
Responsables Unitats de KTT	1 dona	3 homes
Investigadors/es de projecte	7	11
Gestió	39	25

Comunicació i divulgació

70 activitats de divulgació

6.500 persones

757 aparicions en premsa

30.861 seguidors a les xarxes socials

Formació i talent

20 tesis doctorals defensades

30 seminaris científics

97 formacions

25 sessions SHARP*

*Seveo Ochoa PhD Training Programme

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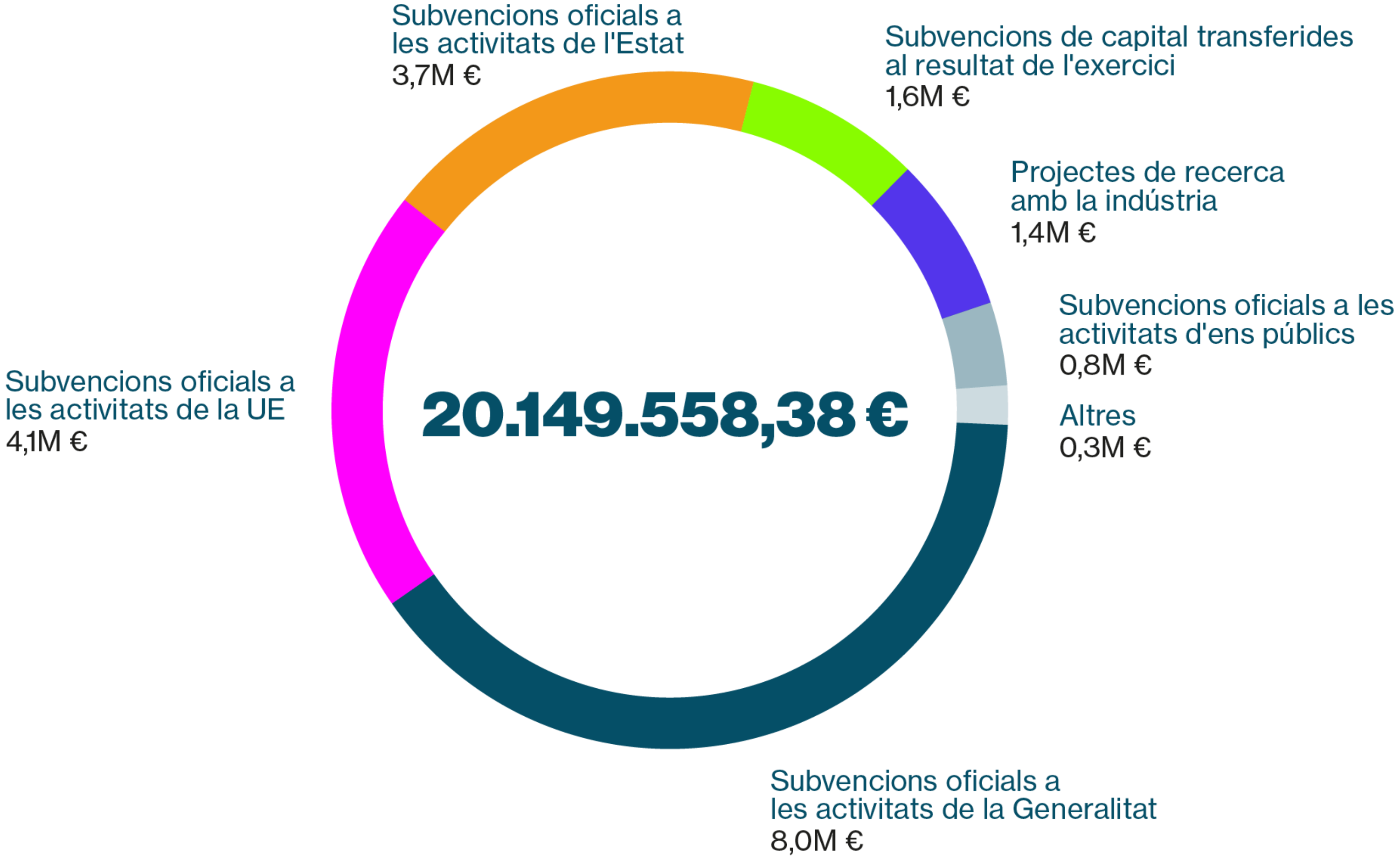
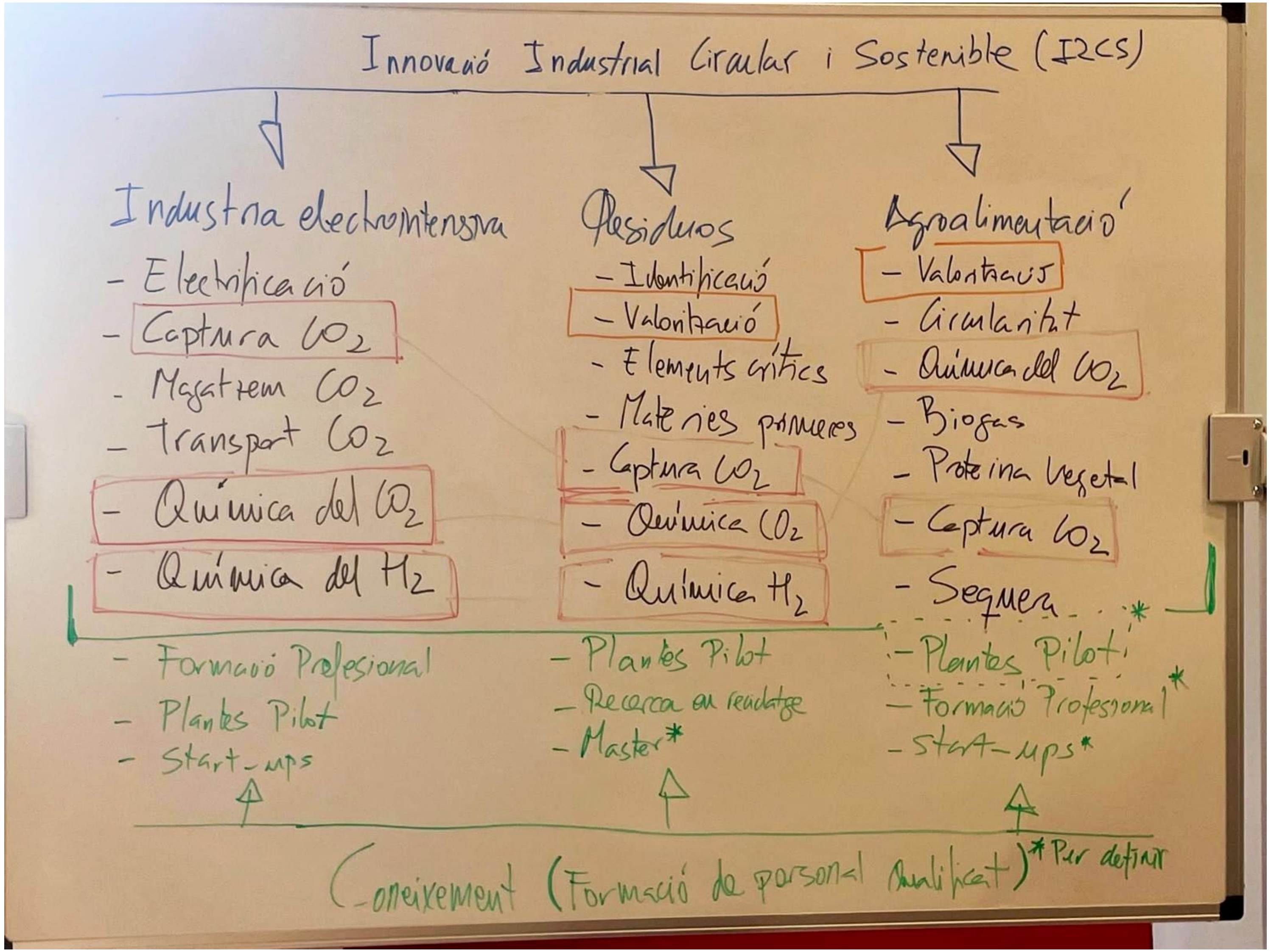
ICIQ **Finances**





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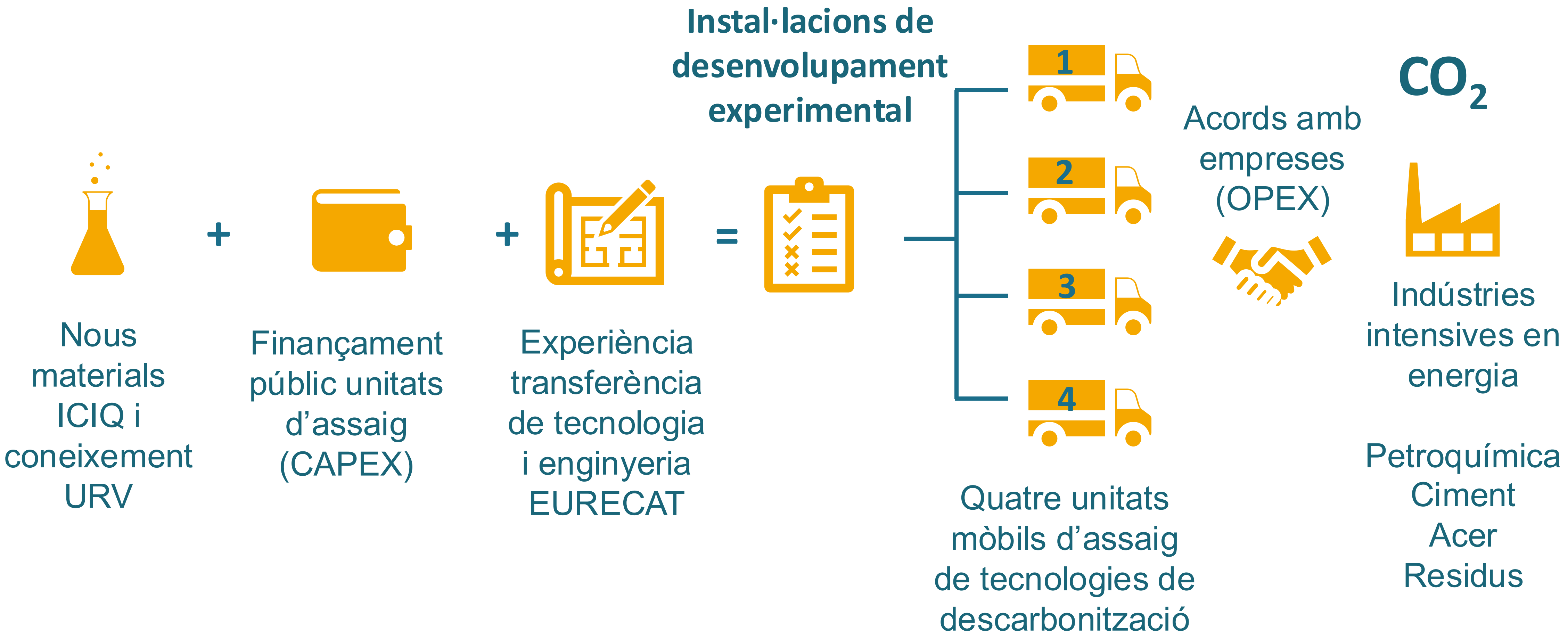
Visió general del projecte



Objectius del projecte

TECNOLOGIA

> Dissenyar i assajar quatre tecnologies diferents de captura i ús de CO_2.

RECERCA I INNOVACIÓ

> Avançar en la maduresa tecnològica de TRL4/5 a TRL6/7.

COL·LABORACIÓ EFECTIVA

> Desenvolupar una col·laboració sòlida entre agents del coneixe-ment i indústria del territori.

SOSTENIBILITAT

> Assajar solucions pre-industrials per contribuir als objectius de zero emissions de CO_2.

ICIQ **Àrees de recerca**

Catàlisi sostenible	Energies renovables	Medicina molecular
Catàlisi i mecanismes Química supramolecular Fotoquímica Conversió de CO_2	Captura i emmagatzematge de CO_2 Fotosíntesi artificial Hidrogen i combustibles sostenibles Materials i polímers Cel·les solars	Química mèdica Sensors químics

Excel·lència aconseguida mitjançant sinèrgies entre investigació **computacional** i **experimental**

02.

Examples from Prof. Arjan Kleij's group

Use of monomers derived from biomass

- Monomers derived from biomass and waste
- Chemical modification of starting monomers and final polymer in order to fine-tune polymer properties
- Platform to provide several sustainable polymer types:
    - Polycarbonates
    - Polyesters
    - Polyethers
    - Other polymers…
- Catalysts (Al, Fe, Cr) designed in-house
    - Polymers with incorporation of CO_2
    - Polymers as fossil-fuel substitute or to increase bio-sourced contents

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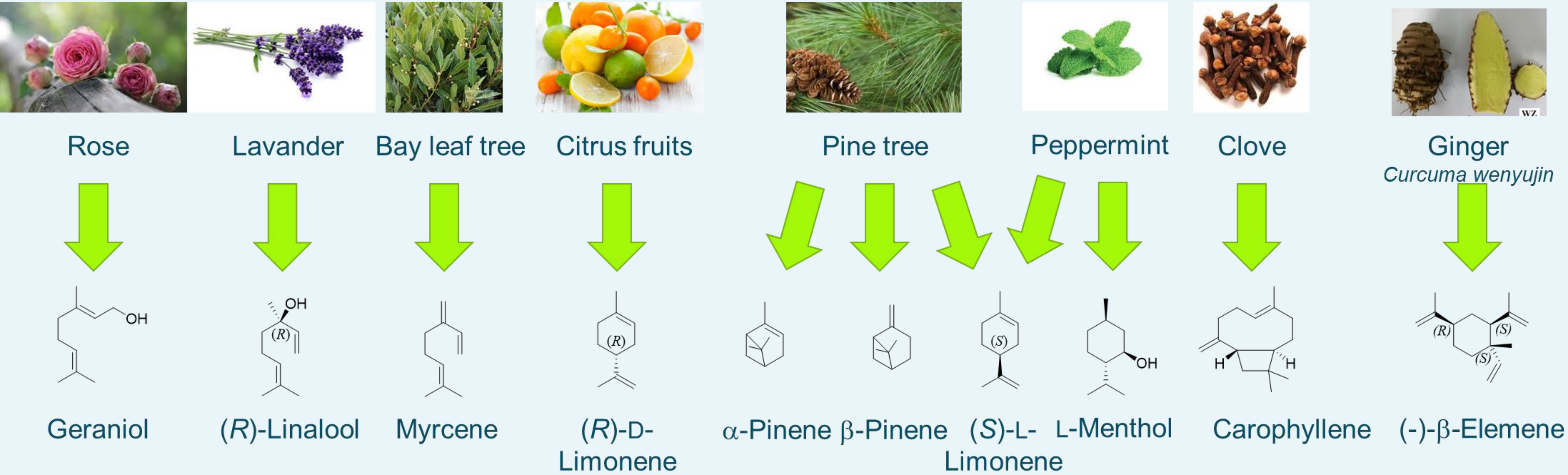
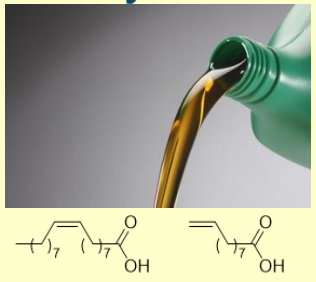
Monomers employed

Terpenes

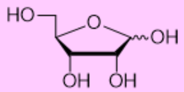


Fatty acids



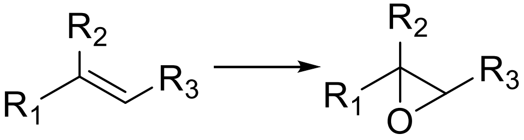
Oleic acid Caproleic acid

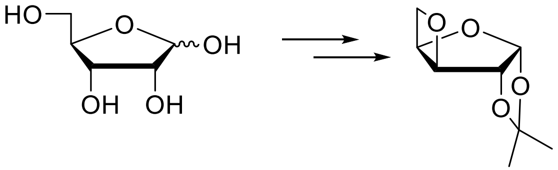
Sugars



Ribose

Activation of the monomers





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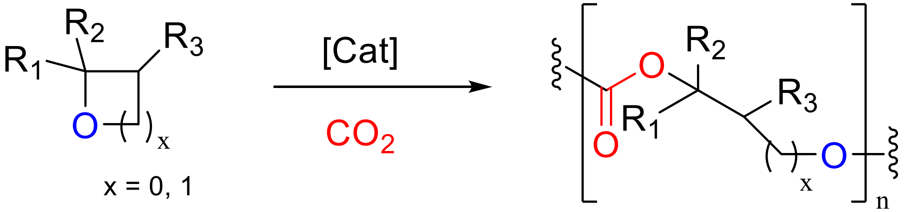
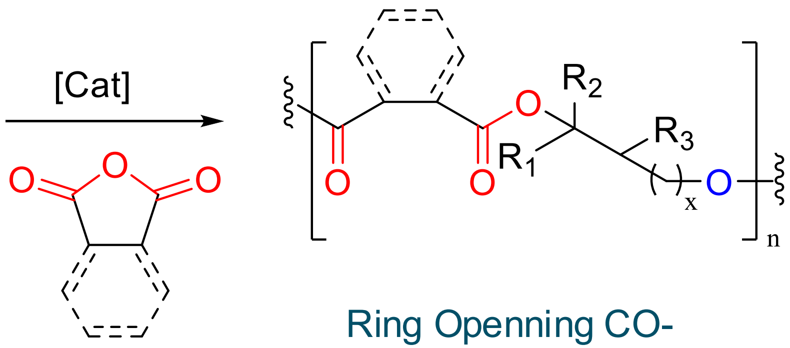
Polymerization



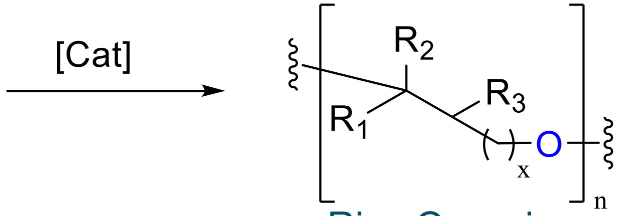
Ring Openning CO-Polymerization (ROCOP)

Polycarbonate



Ring Openning CO-Polymerization (ROCOP)

Polyester



Ring Openning Polymerization (ROP)

Polyether

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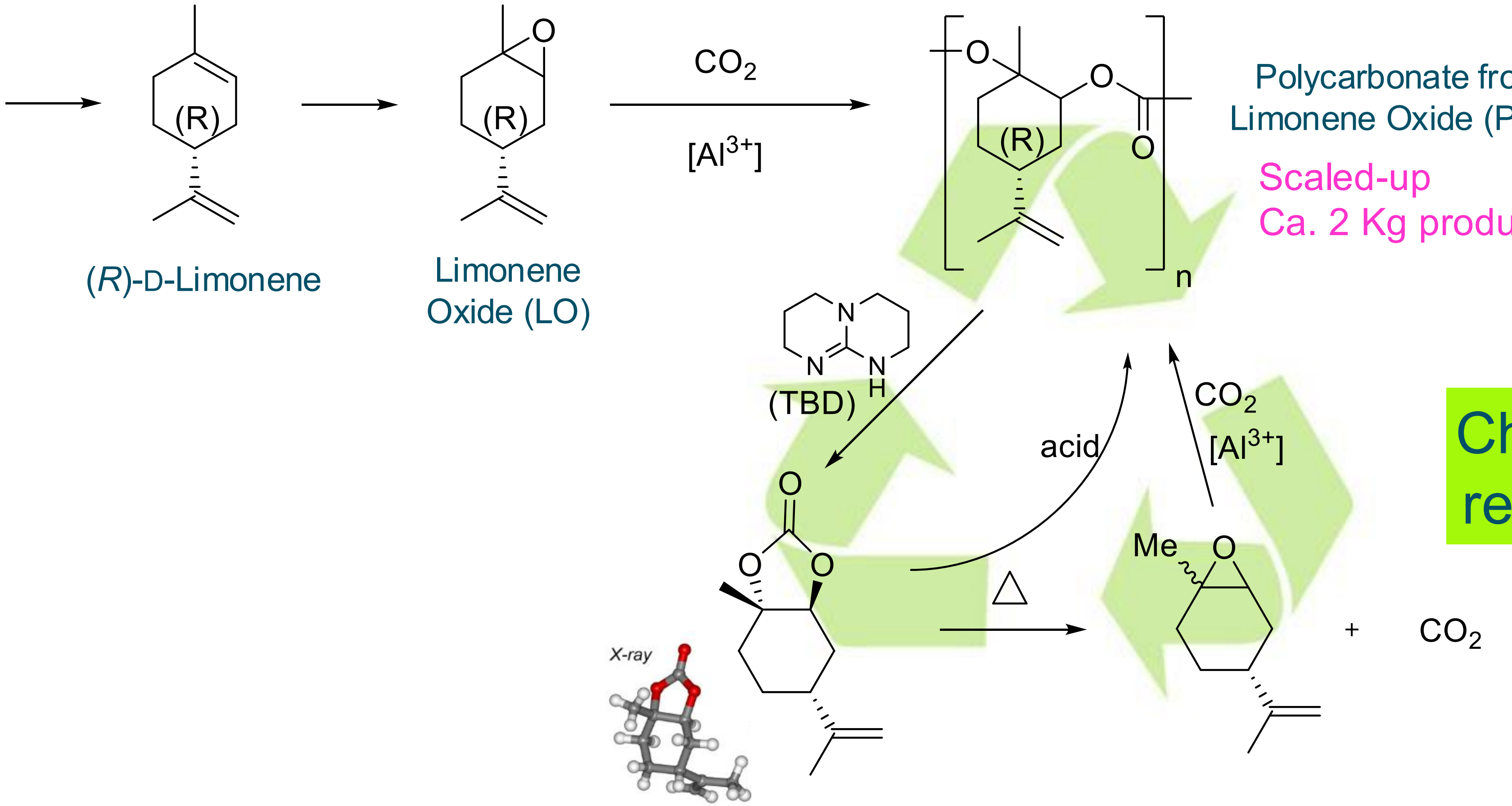
Examples

(with ICIQ-KTT Innovation and Valorization Laboratory)

Citrus peels (waste)



Scaled-up
Ca. 2 Kg produced

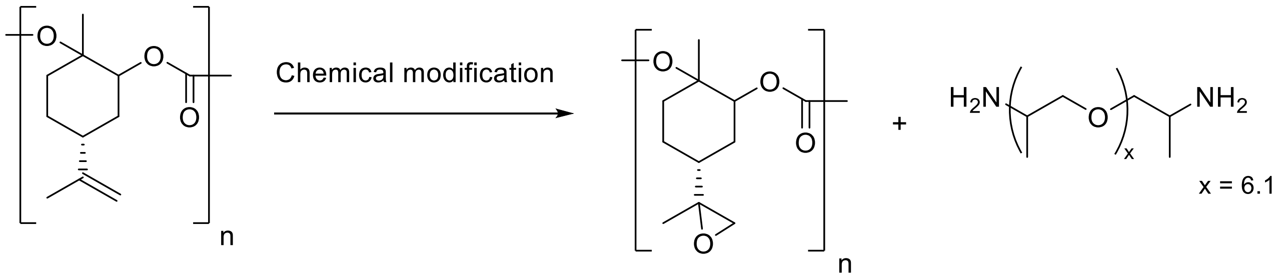
Chemical recycling

Angew. Chem. Int. Ed. **2023**, *62*, e202314659

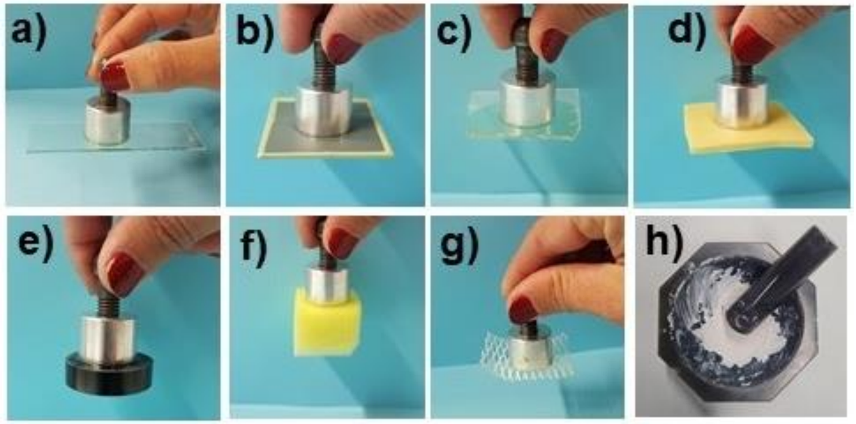
Examples of applications

Adhesives and coatings

(with ICIQ-KTT Innovation and Valorization Laboratory and UPC)



Cross-linking

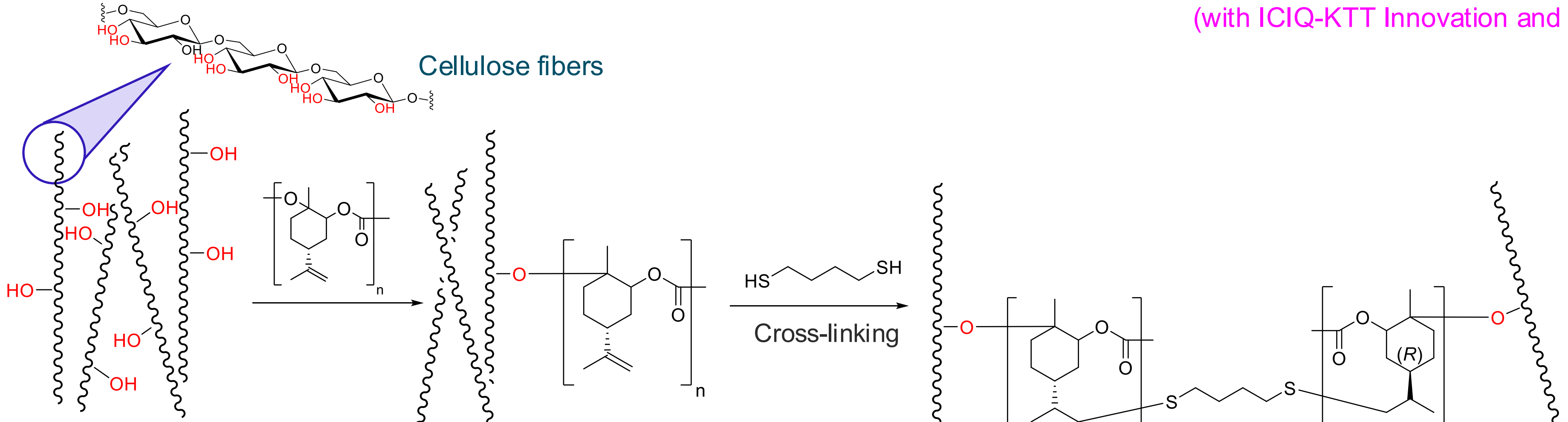


ACS Sustainable Chem. Eng. **2022**, *10*, 2708-2719

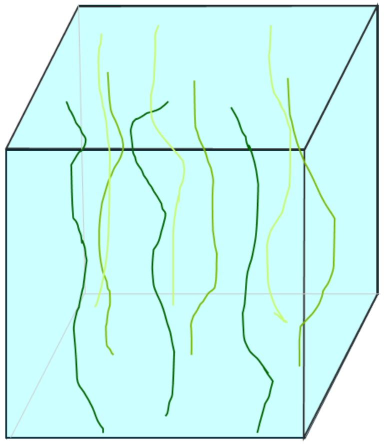
ChemSusChem **2022**, e202102624

Composite materials providing structural strength

(with ICIQ-KTT Innovation and Valorization Laboratory and U. Potsdam)



Covalently-bonded PLC to Cellulose Fibers



WO2025/195720

Cellulose fibers covalently-embedded within a PLC matrix: biosourced materials in matrix (PLC) and reinforcement (cellulose)

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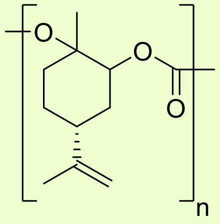
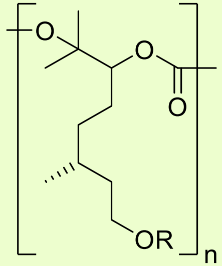
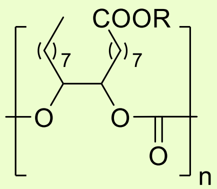
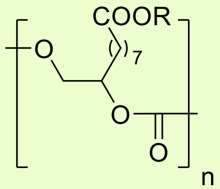
Examples of bio-polymers prepared

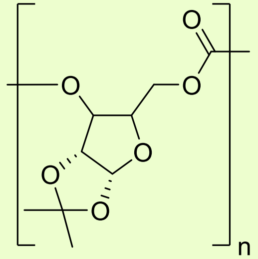
Polycarbonates

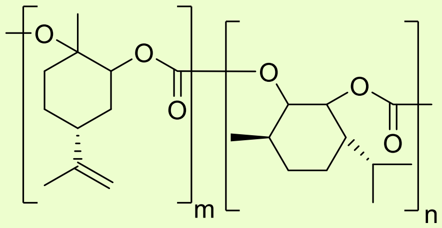

Polycarbonate from Limonene (PLC)

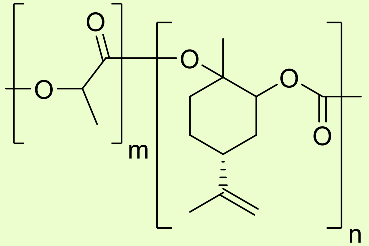

Polycarbonate from Citronellol


Polycarbonate from Oleic Acid

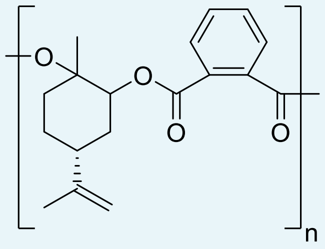

Polycarbonate from Caproleic Acid

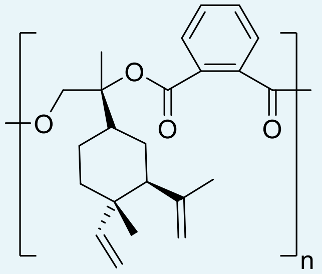

Polycarbonate from Ribose

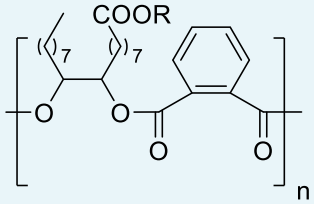

Polycarbonate from Limonene + Menthene

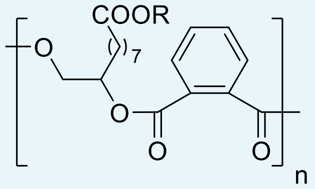

Block co-polymer: Polyester from Lactic Acid (PLA) and Polycarbonate from Limonene (PLC)

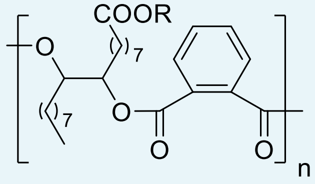
Polyesters

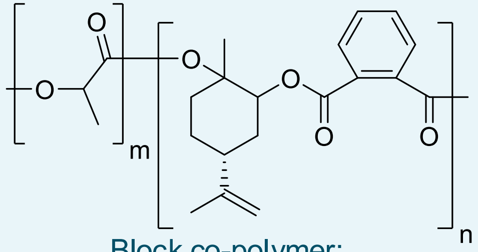

Polyester from Limonene + Phthalic Anhydride

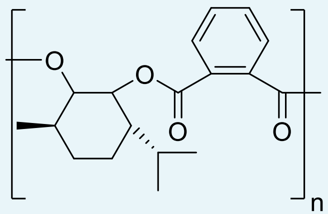

Polyester from β-elemene + Phthalic Anhydride

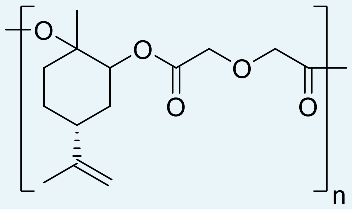

Polyester from Oleic Acid + Phthalic Anhydride

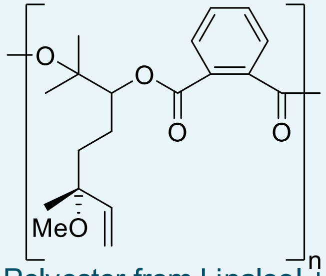

Polyester from Caproleic Acid + Phthalic Anhydride

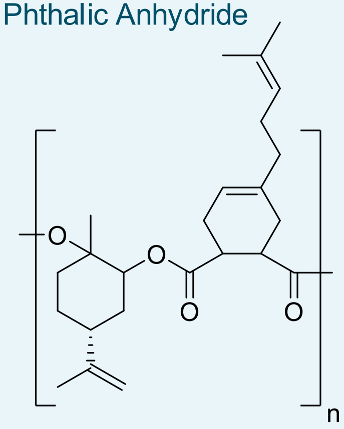

Polyester from Elaidic Acid + Phthalic Anhydride


Block co-polymer: Polyester from Lactic Acid (PLA) and Polyester from Limonene + Phthalic Anhydride

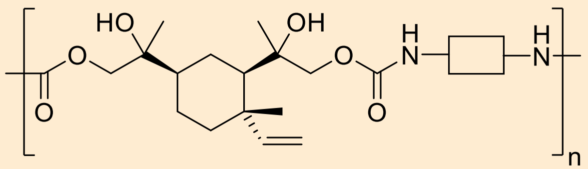

Polyester from Menthol + Phthalic Anhydride


Polyester from Limonene + Glycolic Anhydride


Polyester from Linalool + Phthalic Anhydride


Polyester from Limonene + Myrcene-derived Anhydride

Polyurethanes

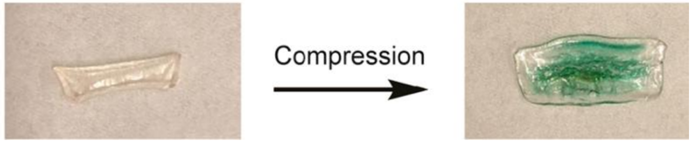

Polyurethane from β-elemene + diamine

03.

Examples from Dr. José Berrocal's group

Smart polymers with response towards external stimuli

- Smart polymers
- Provide a macroscopic response:
  - Change of color
  - Reorganization
  - Self-healing materials
  - …



- Response to:
  - Light
  - Mechanical stress
  - Magnetic field
  - Temperature
  - Moisture
  - Changes in pH
  - …

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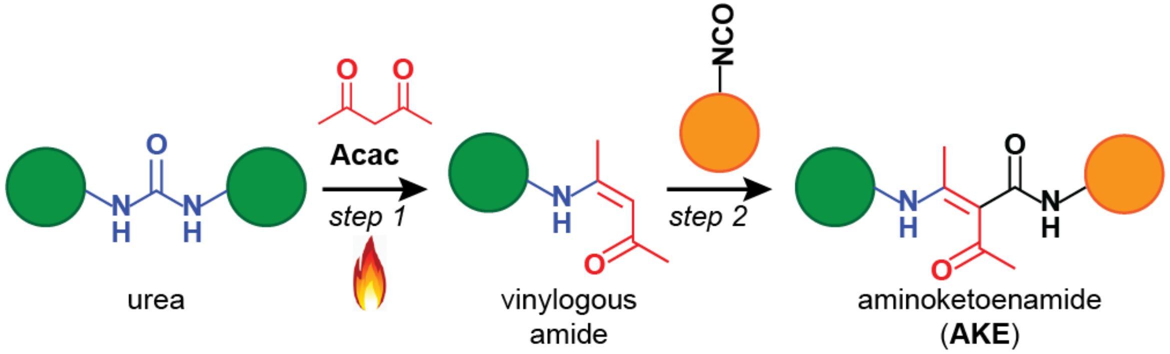
Chemical recycling of polyureas

Polyureas:

- Outstanding properties

… but

- Challenging to recycle



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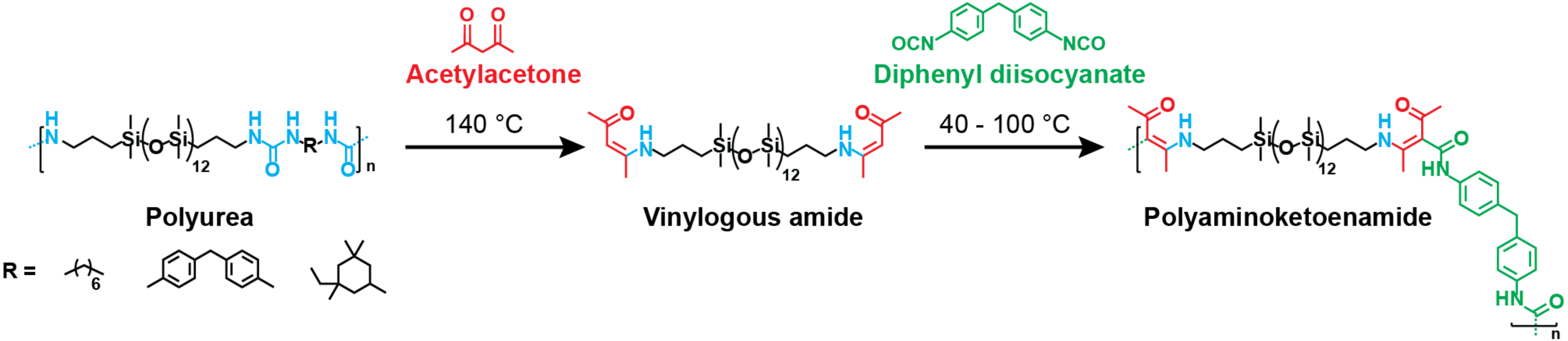
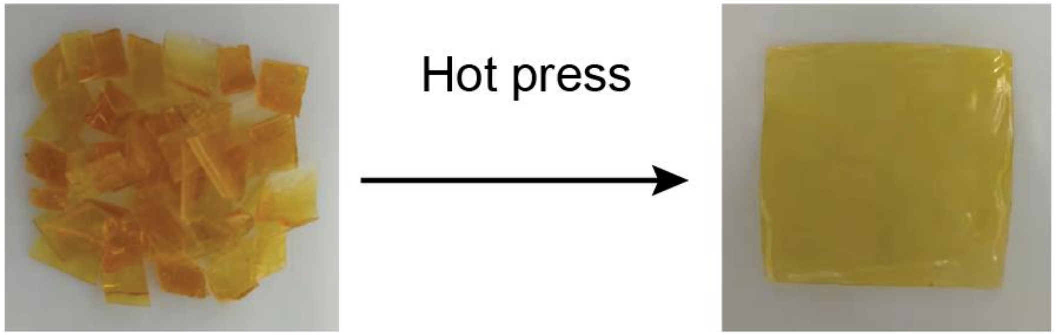
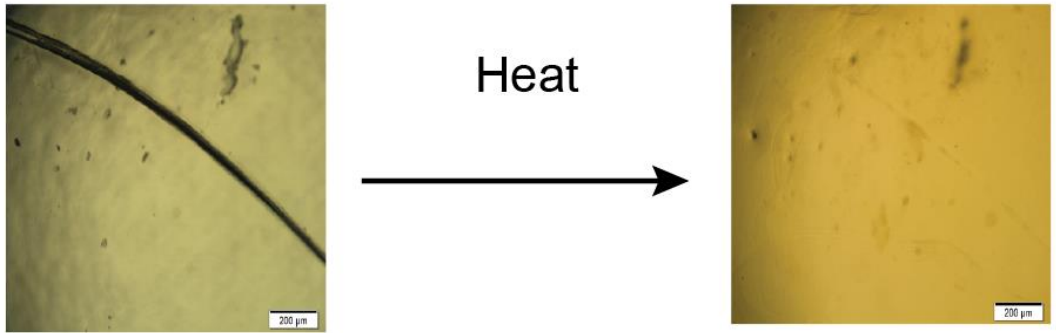
Chemical recycling of polyureas



Thermal reprocessing of polyaminoketoenamides



Thermal healing of polyaminoketoenamides



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Angew. Chem. Int. Ed. Engl. **2023**, *62*, e2022128

04.

New inks for 3D-photoprinters

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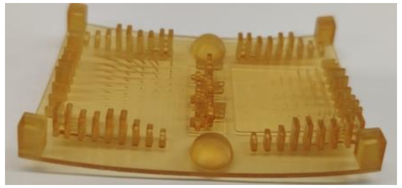
ICIQ-KTT Innovation and Valorization Laboratory with UPC

- Photopolymerizable ink from Phenylalanine
  - Biodegradable
  - Non-toxic

Monomer	Linker	Reactive solvent	Photoinitiator (type I)	UV absorber
"PADEG"	PEG-DA 250	dimethylacrylamide	BAPO	2,5-Bis(5-^{t}butyl-benzoxazol-2-yl)thiophene
18,02 %(w/w)	36,04 %(w/w)	45,04 %(w/w)	0,50 %(w/w)	0,40 %(w/w)

Macromol. Rapid Commun. **2023**, 2300132

Excellent piece resolution ☑
Resistant pieces, in all dimensions ☑
Colored pieces ☒

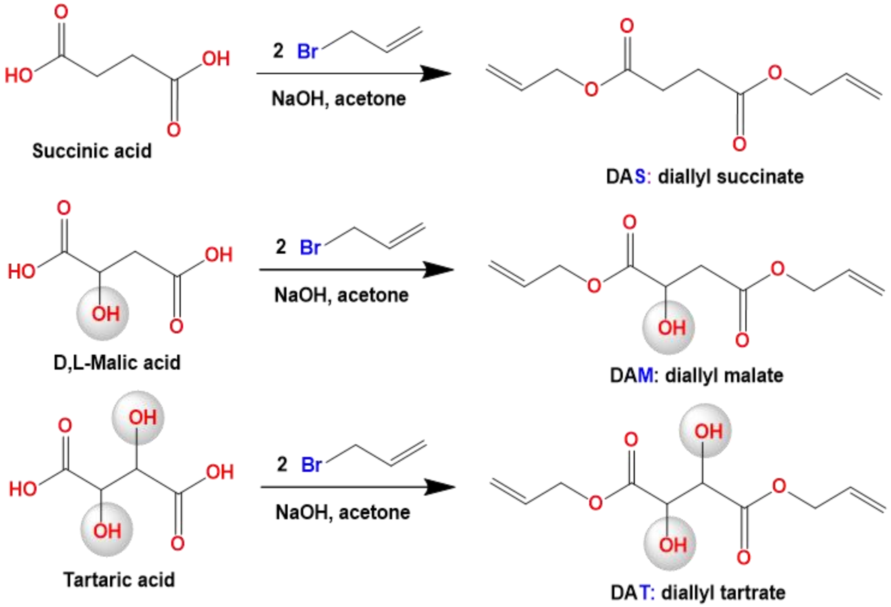


- Photopolymerizable ink from biomass

Corn

Apple

Grapes



+ PEGDA
+ BAPO

+ PEGDA
+ BAPO

+ PEGDA
+ BAPO

- Biodegradable

Colorless ☑
Weaker pieces ☒
Worst resolution ☒

RSC Appl. Polym. **2024**, 2, 284-295

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