6a Conferenza Nazionale Poliuretano Espanso rigido - Obiettivo: Emissioni ZERO

Torino 30 Maggio 2024

Consiglio Nazionale delle Ricerche

New *Sustainable* trends in rigid polyurethane foams

ANPE - 6a Conferenza Nazionale

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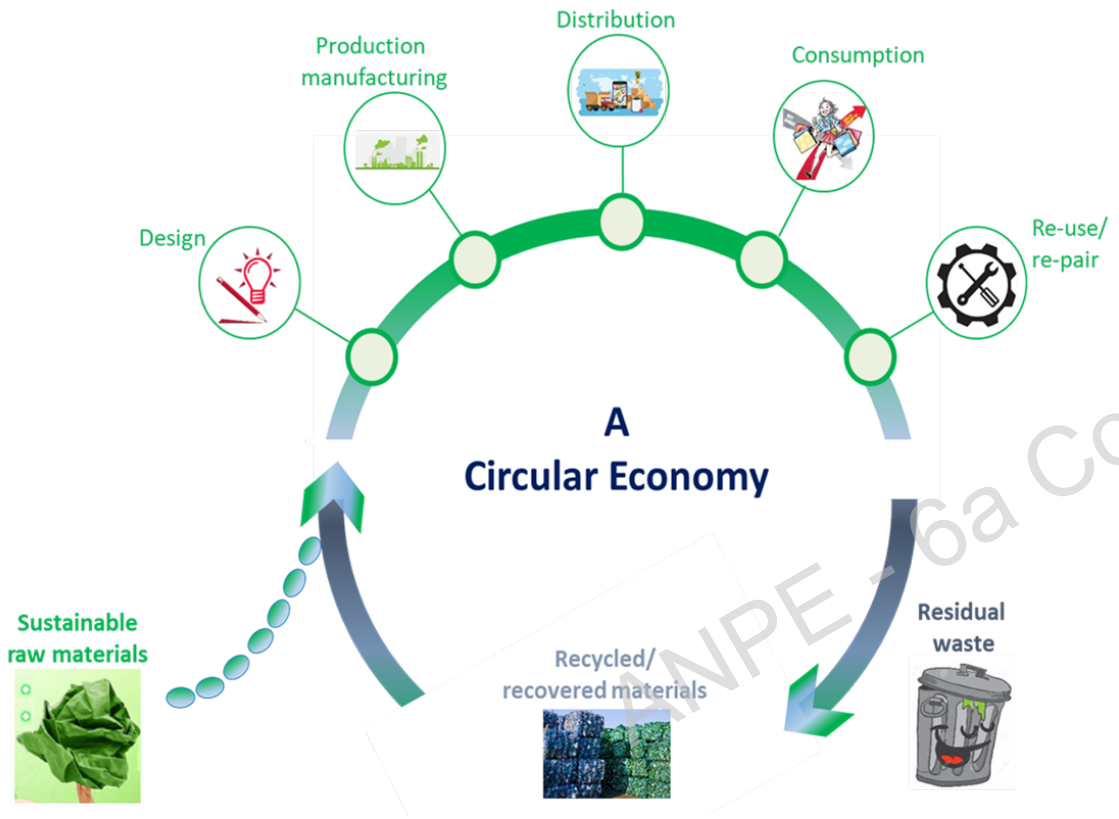
RI-thinking the Materials: *R*educe, *R*euse, *R*ecycle

Become fully circular by following a philosophy of continuous research and implementation of more sustainable material solutions.



Multifunctional Sustainable Polyurethane foams:

Multifunctional smart composite materials based on sustainable polyurethane foam and functional filler for health monitoring of *new* and *historical* buildings and automotive- **HERITAGE and BIOMAT EU projects**

Composite Sustainable Non Isocyanate PolyUrethane foams- CNIPU- **GREENART** EU **project**

Multifunctional composite sustainable polyurethane foam packaging for Cultural Heritage application (safe transport and conservation of artifacts)-**GREENART** EU **project**

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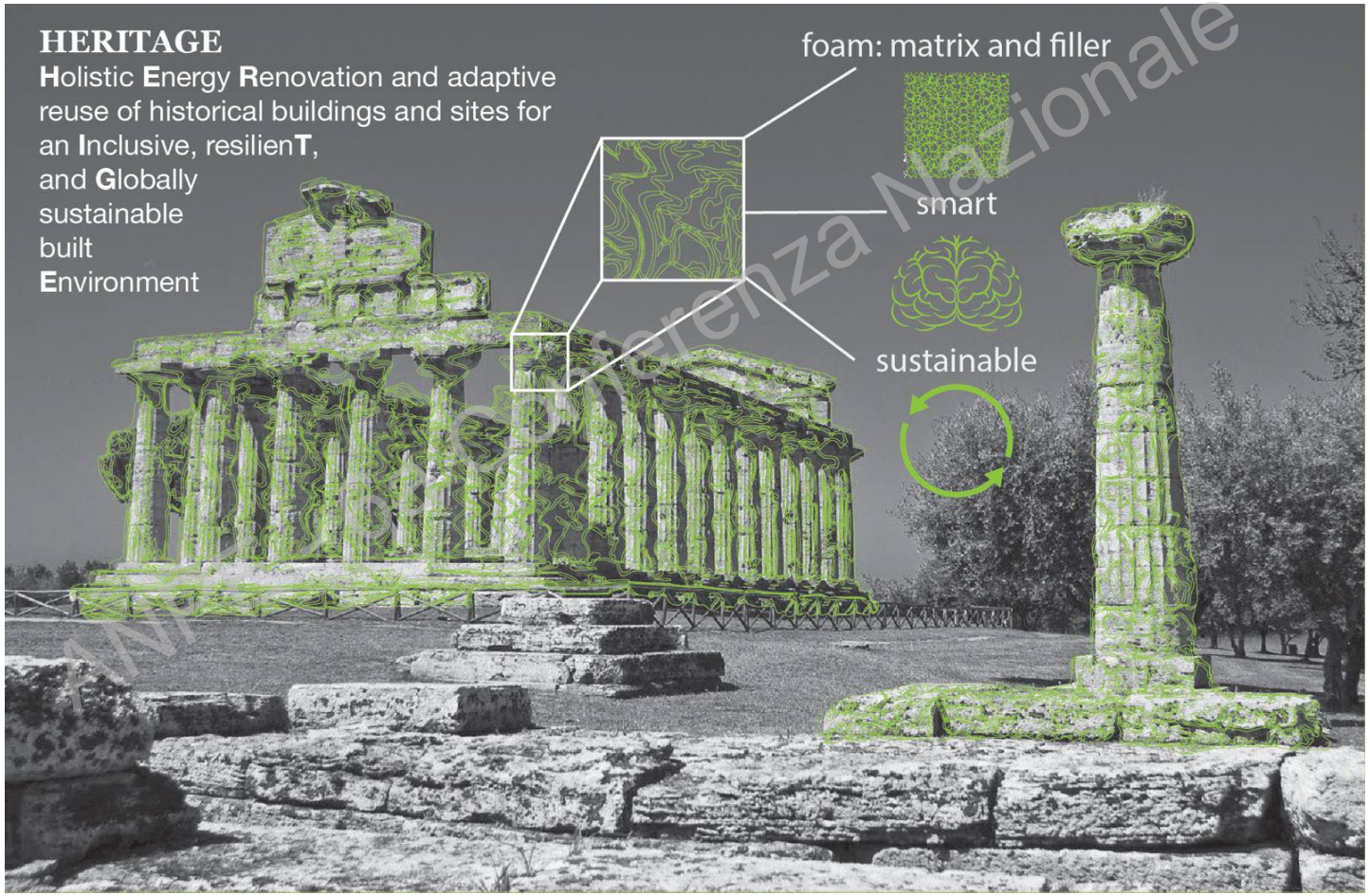
Multifunctional smart composite materials based on rigid sustainable polyurethane foam

Target

health monitoring of buildings



AIM Copia Conferenza Nazionale

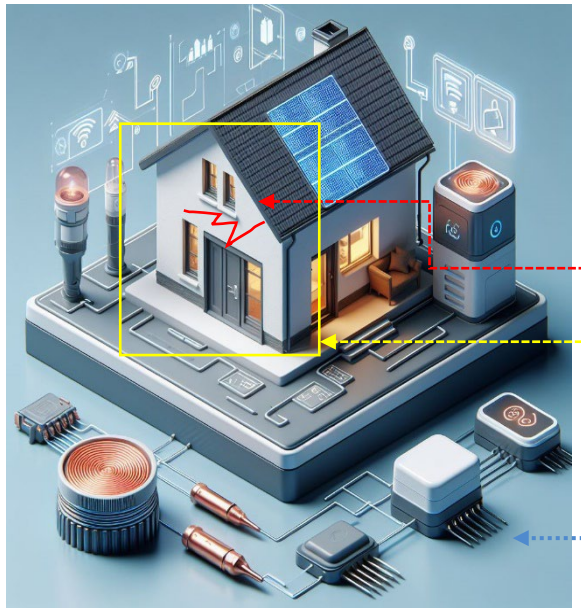
Multifunctional smart composite materials based on rigid sustainable polyurethane foam

HERITAGE

How?

Tailored architecture of filler morphology

monitored structure

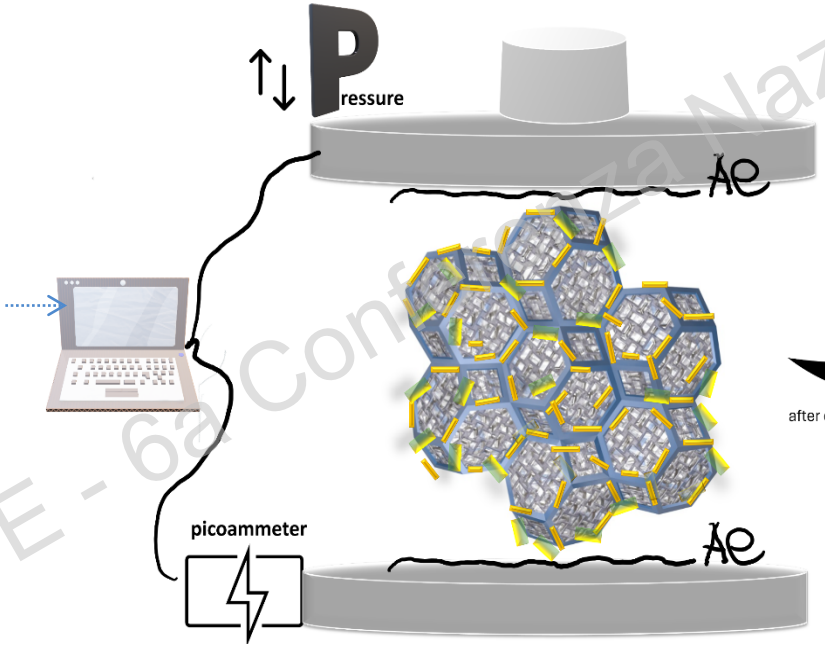


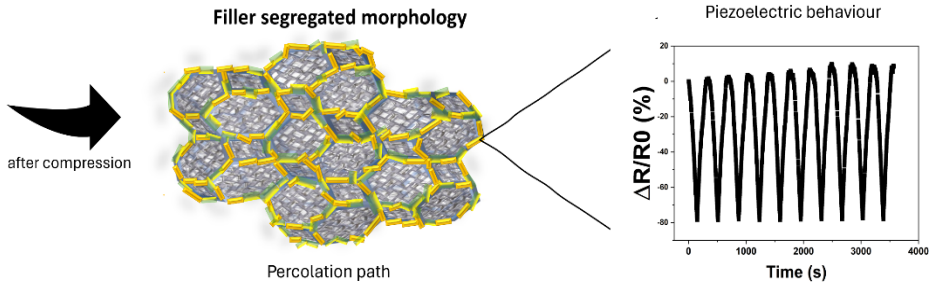
damage:
Structural failure, hearthquake, fire, gas, material aging..

monitoring point

data acquisition

Electromechanical test





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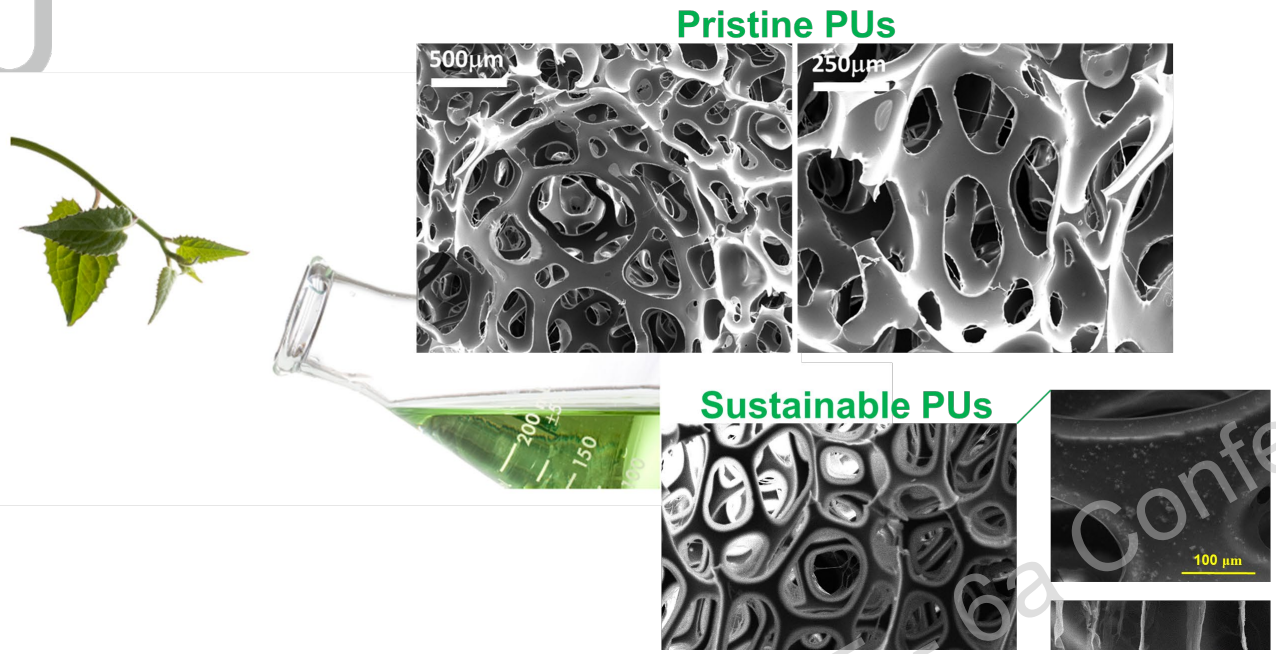
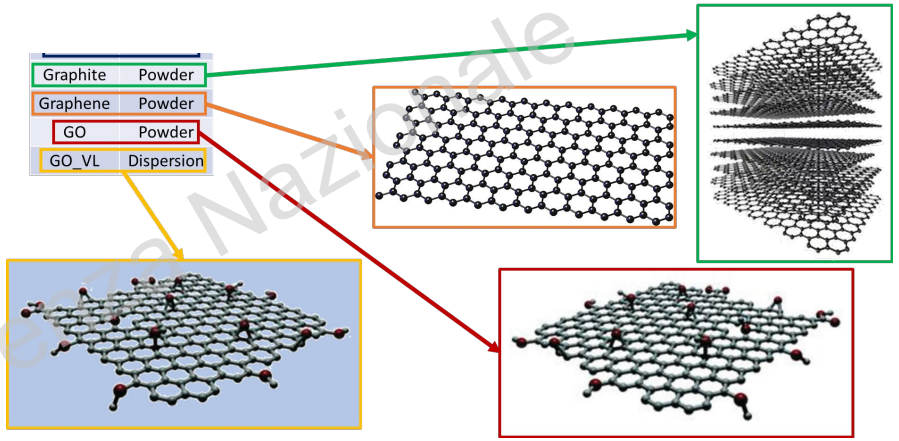
To monitor the health of an infrastructure, multifunctional material (based on the combination of **electrically conductive filler**, **carbon/graphene- based, ZnO** etc, and PUR foam as matrix) can be used in the building, to monitor stress, deformation damage, aging etc., by measuring the change in electrical properties of the composite under external load.

Verdolotti, L. Sci Rep 11, 18975 (2021)

Multifunctional smart composite materials based on integral sustainable polyurethane foam





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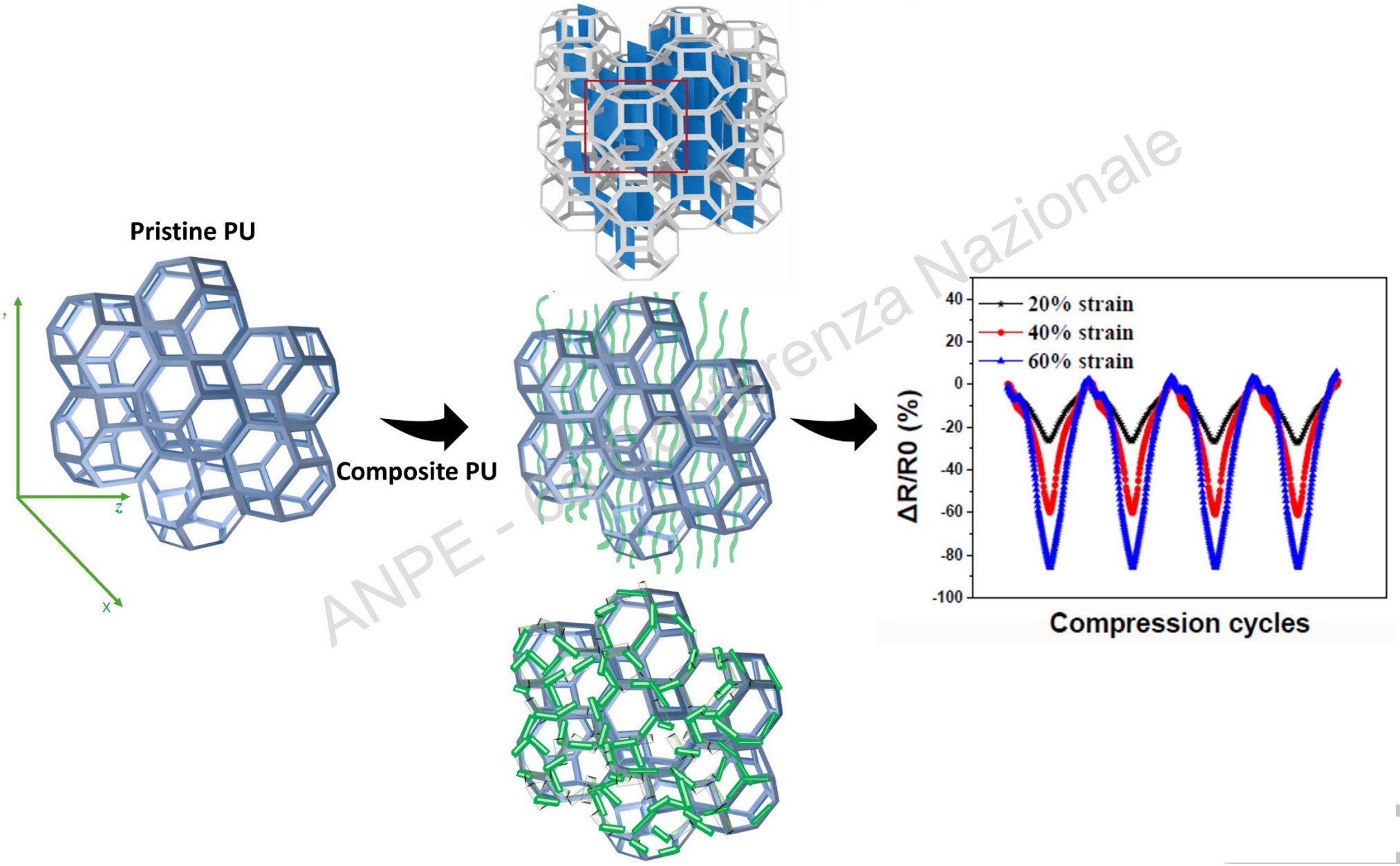
Graphene-based nanofillers, due to their high specific surface area, electrical conductivity, mechanical strength, added in the polymeric matrix at low concentration, affect positively the overall PU foam performances cell and foam density, mechanical performances, thermal degradation, flammability along with functional properties.

Verdolotti et al, Progress in Polymer Science, 2019, 89, pp. 213–249

Multifunctional smart composite materials based on flexible or integral sustainable polyurethane foam

Tailored architecture of filler morphology



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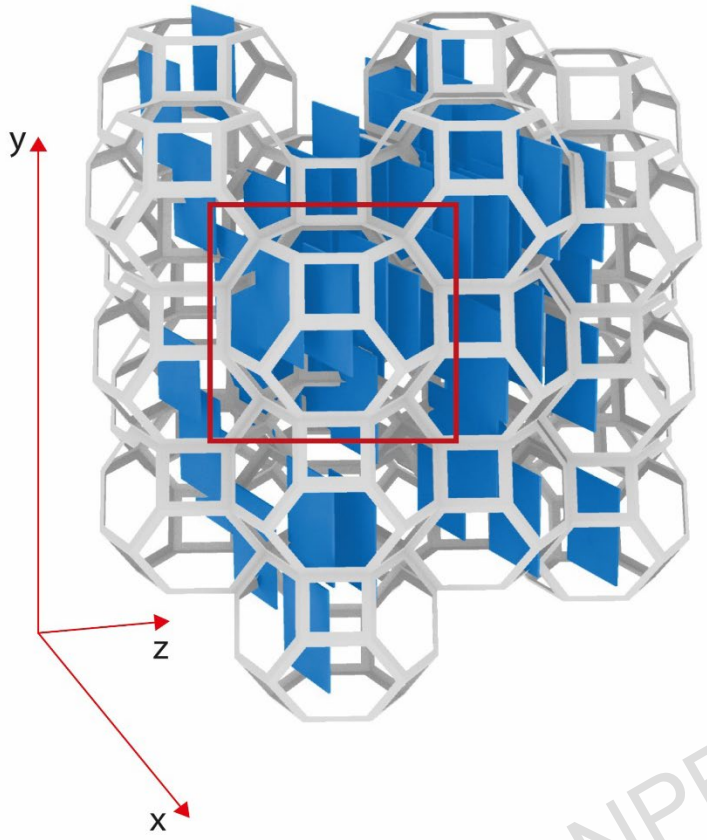
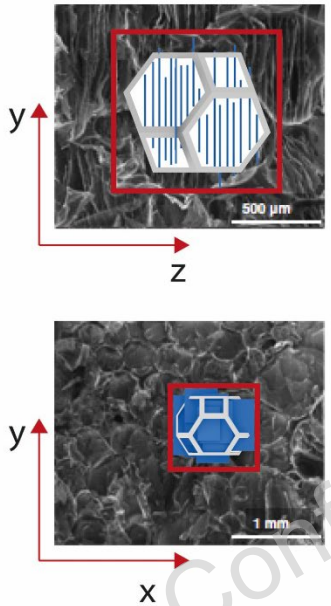
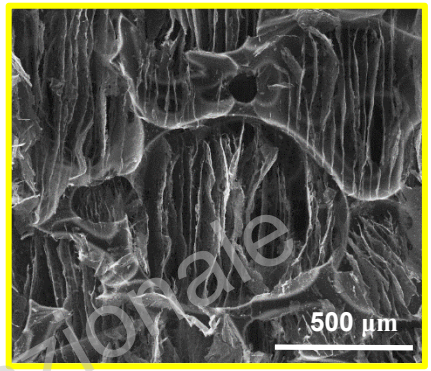
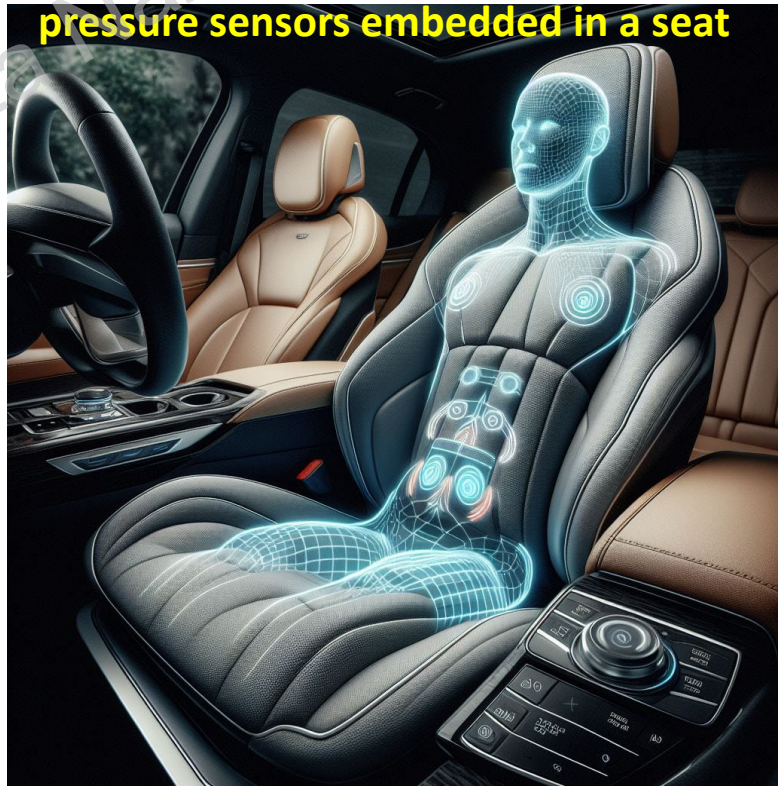
Multifunctional smart sensor based on flexible sustainable polyurethane foam









Functional fillers (carbon, graphite/graphene-based, ZnO, CuO, PCM…) suitably integrated into PU foam, could allow to monitor the driver's changing posture or to improve the comfort of the driver by including suitable functionality i.e. thermoregulation (through the Joule effect), thermal conductivity (to dissipate/transfer heat from hot-spots under boundary conditions such as excessive heat/cold)

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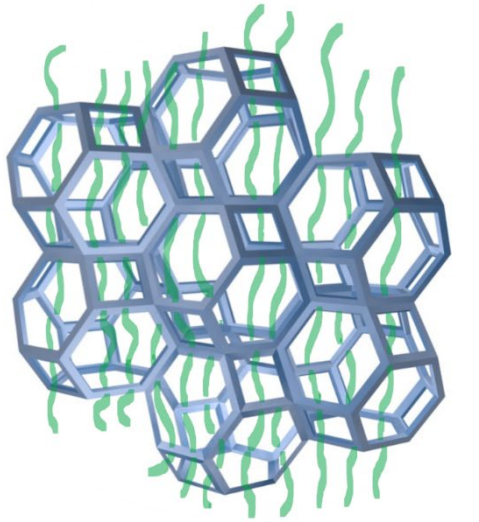
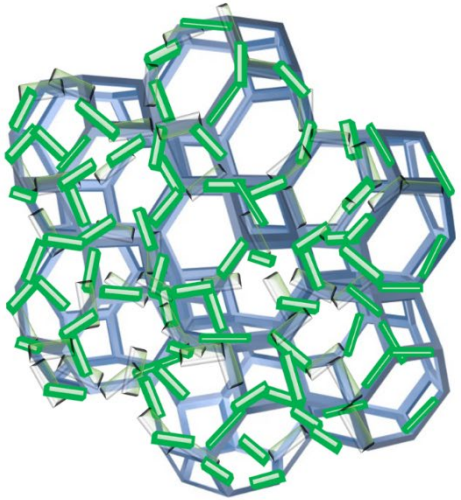
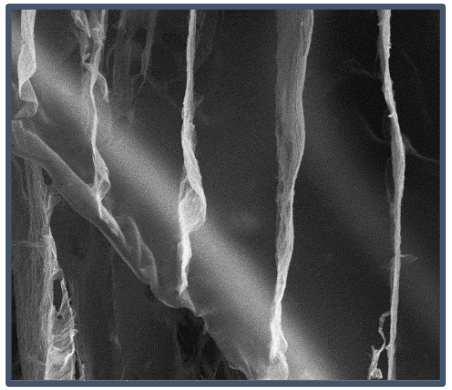
Multifunctional smart sensor based on flexible sustainable polyurethane foam







hot

cold

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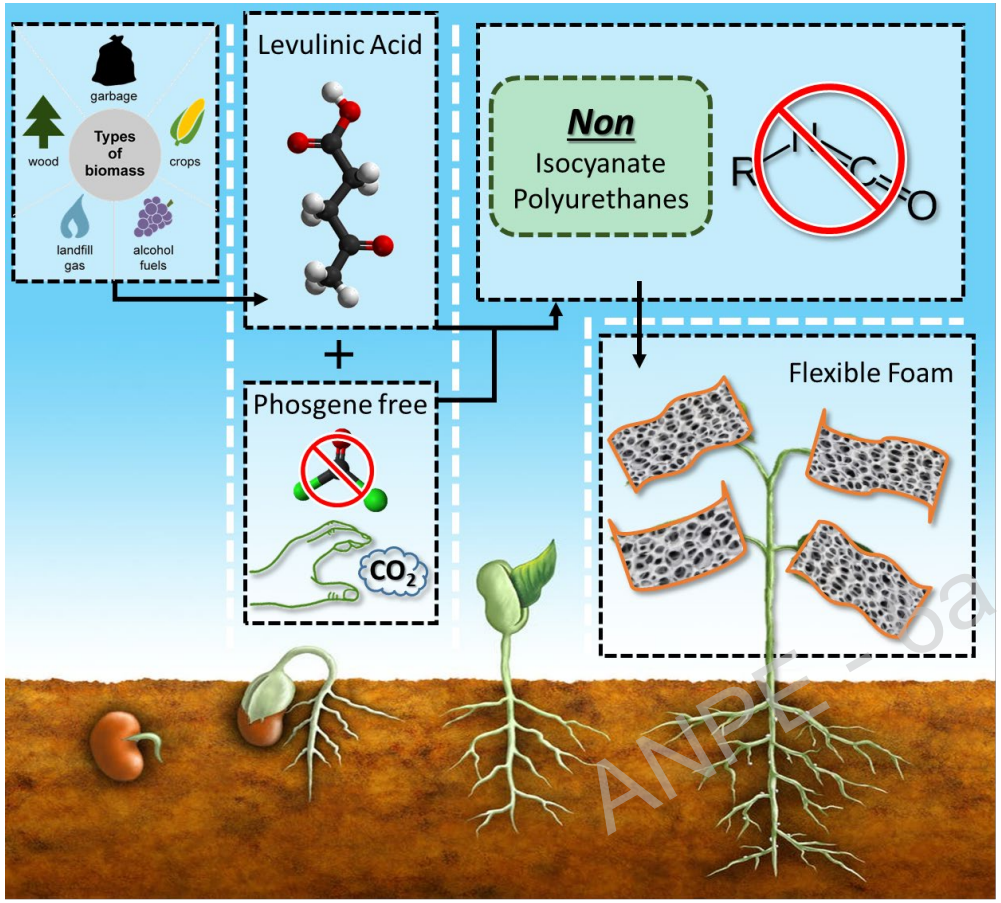
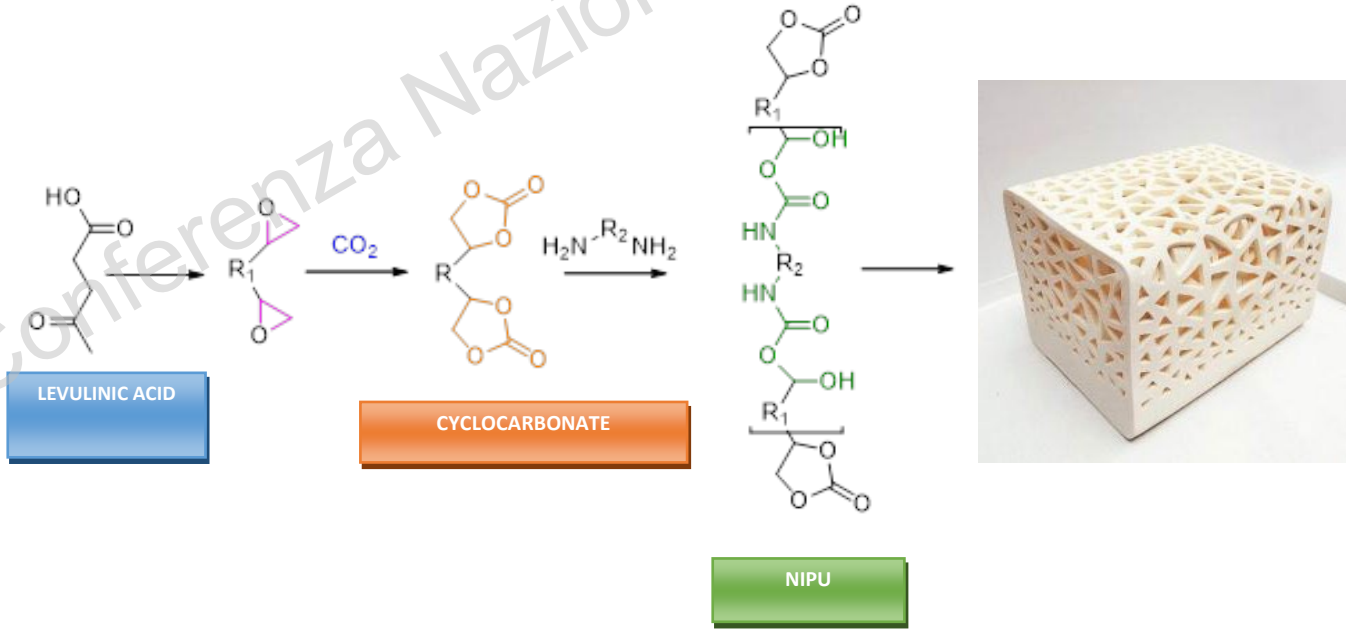
Functional fillers (carbon, graphite/graphene-based, ZnO, CuO, PCM…) suitably integrated into the integral IPU foam, could allow to monitor the driver's driving style by assessing the pressure she/he puts on the steering wheel or to have suitable functionality i.e. thermoregulation (through the Joule effect), thermal conductivity (to dissipate/transfer heat from hot-spots under boundary conditions such as excessive heat/cold)

Composite Sustainable Non Isocyanate PolyUrethane foams-CNIPU





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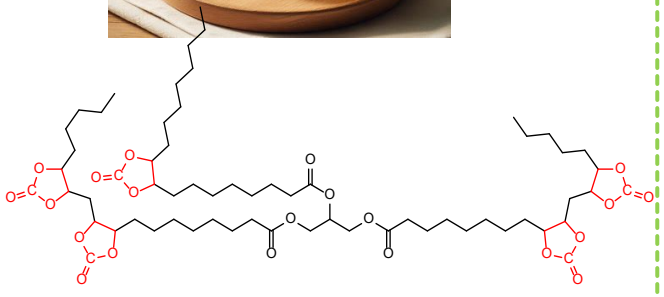
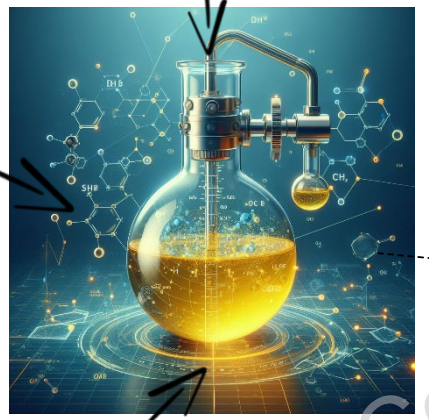
Composite Sustainable Non Isocyanate PolyUrethane foams-CNIPU

Soybean oil-based cyclic carbonate

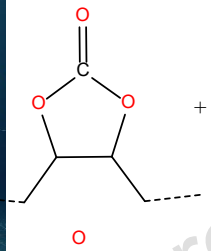


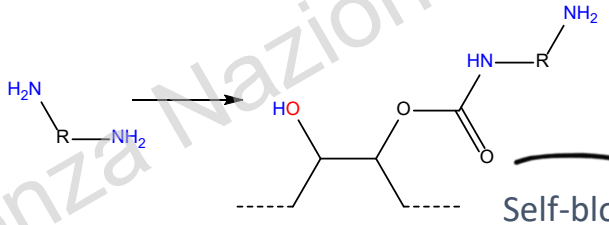
Blend of cyclocarbonate

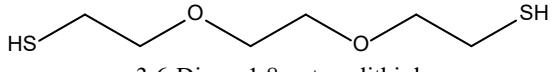
Bio-based diamine



Catalyst and suitable filler (as nucleating agent)

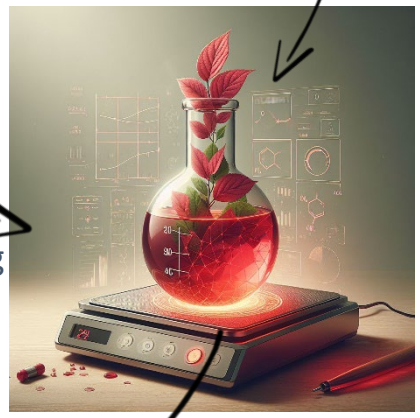


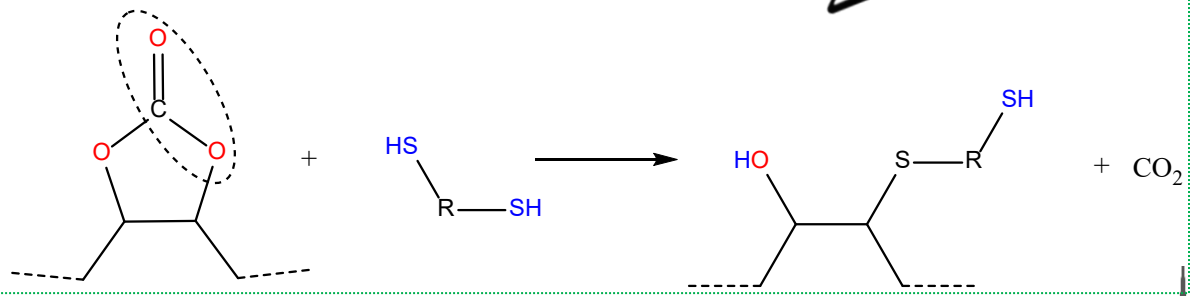




3,6-Dioxa-1,8-octanedithiol

Self-blowing





PolyHydroxyurethane-co-hydroxythioether-NIPU

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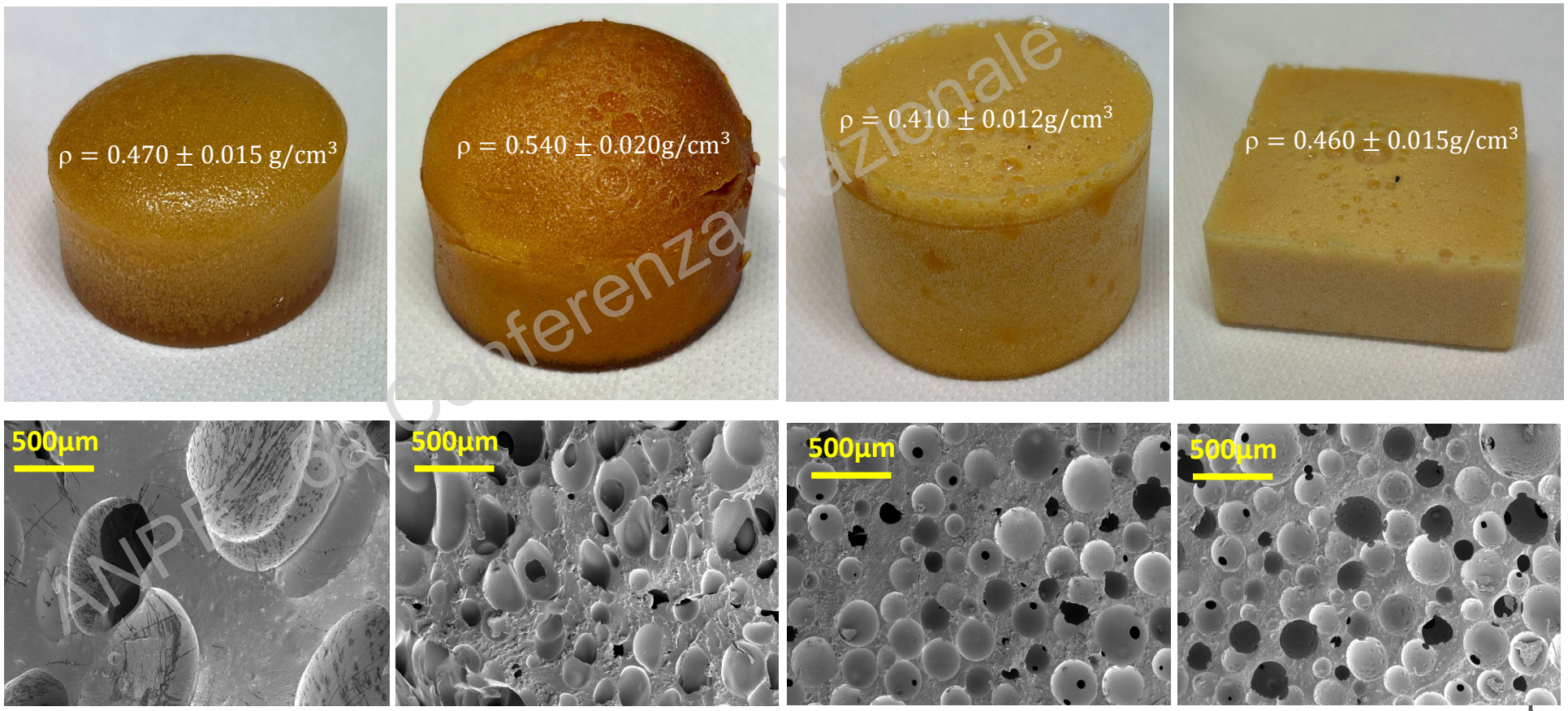
Sustainable Composite Non Isocyanate PolyUrethane foams-CNIPU

Effect of:

- ✓ chemical composition:
  - NH/CC ratio
  - SH/CC
  - Filler amount
- ✓ Process parameters:
  - ✓ Mixing speed
  - ✓ Time mixing
  - ✓ Temperature
- ✓ Shape of mould



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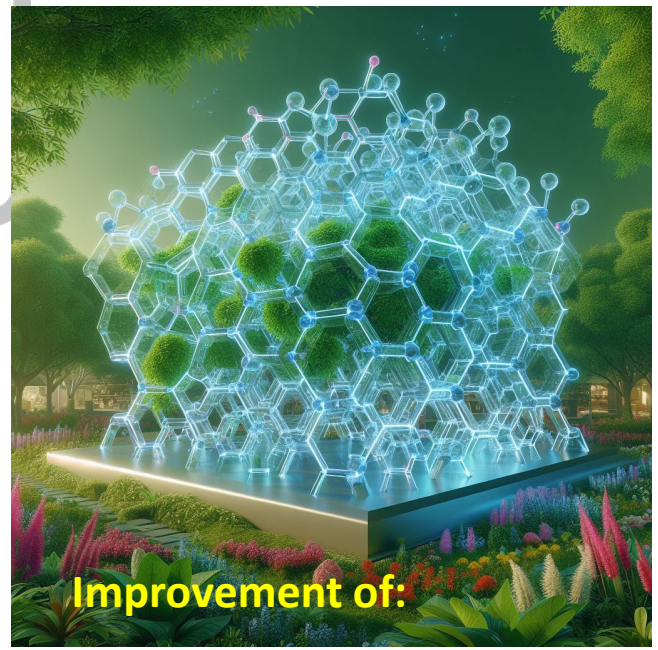
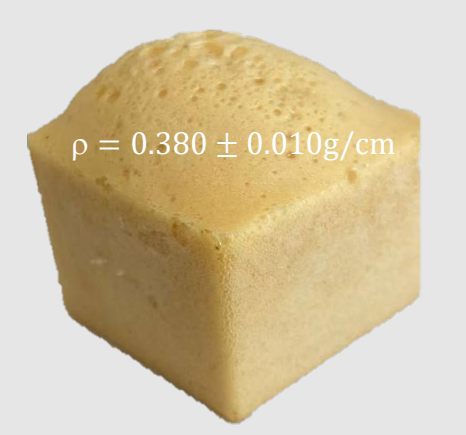
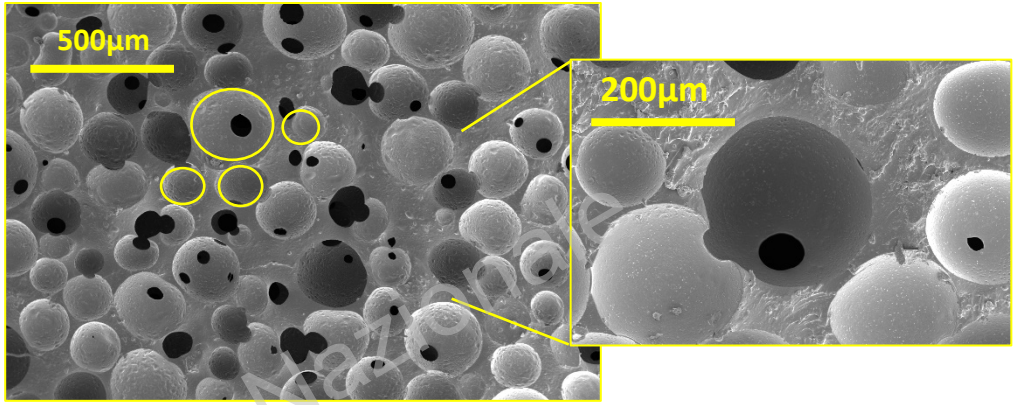
Composite Sustainable Non Isocyanate PolyUrethane foams-CNIPU

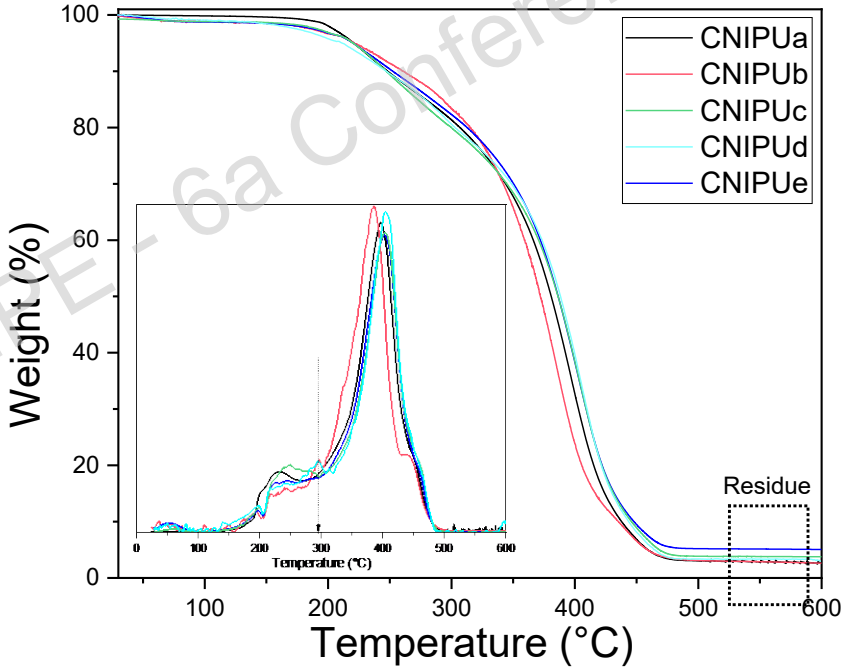


- ✓ Process parameters:
  - ✓ Mixing speed
  - ✓ Time mixing
  - ✓ Temperature
- ✓ Shape of mould





Thermal degradation behaviour



Mechanical performance

Sample	E, MPa
CNIPUa	0.1±0.02
CNIPUb	0.4±0.015
CNIPUc	0.7±0.03
CNIPUd	1.1±0.23
CNIPUe	4.2±0.16

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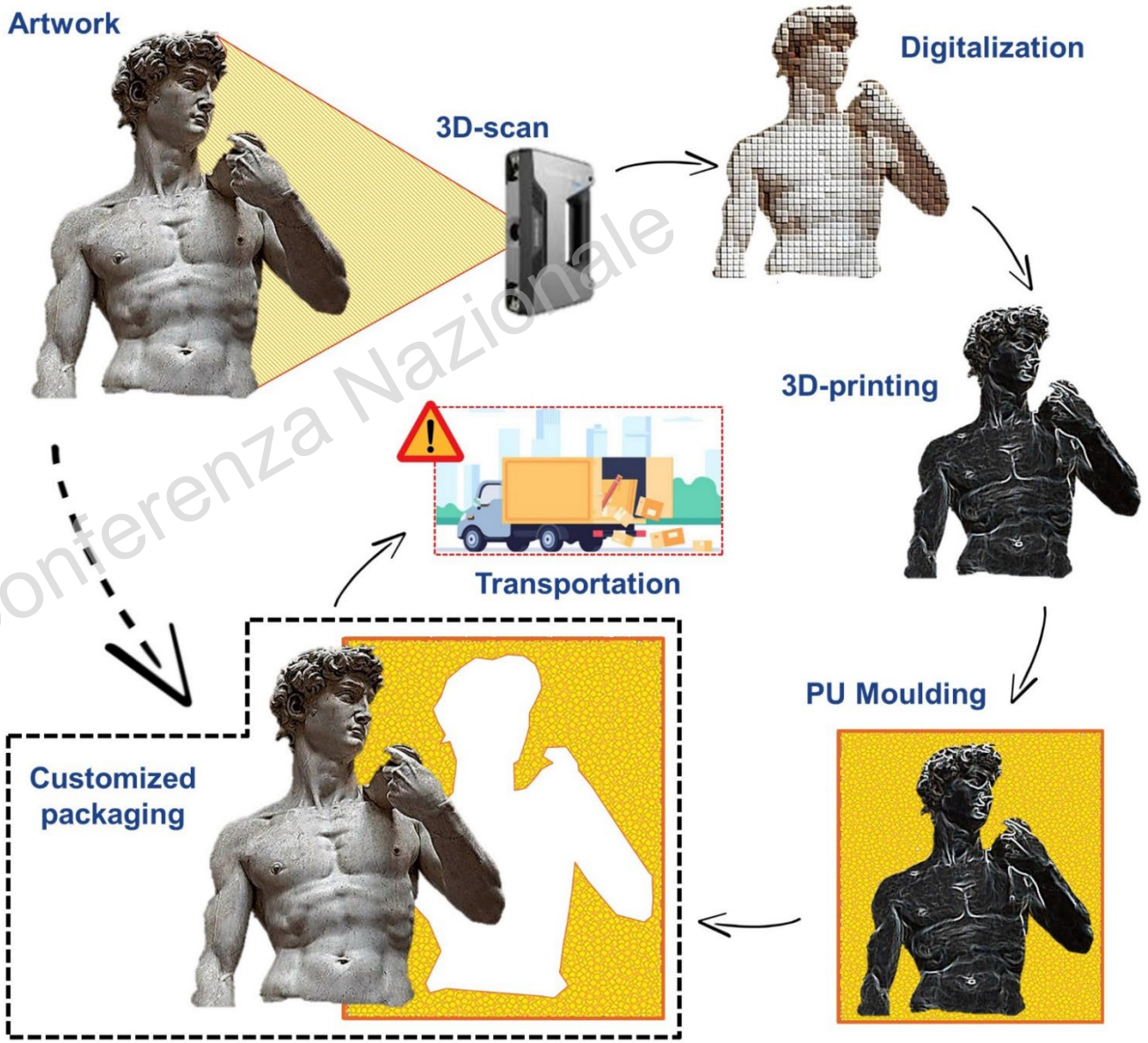
Multifuntional Composite sustainable polyurethane foams for packaging application in cultural heritage

PROOF OF CONCEPT:
«Customizable packaging»

- **Design** of an innovative and multifunctional **sustainable polyurethane foam packaging** with
  - Novel mechanical performances: anti-shock, anti-vibration
  - Improved functional properties:
    - ⇒ high thermal-hygrometric insulation
    - ⇒ high barrier properties against moisture and aggressive agents such as organic pollutants.
- **Customized packaging**
- **Recyclable**



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L. Verdolotti et al, Adv. Eng. Mat. 26(7) (2024)

Impact test

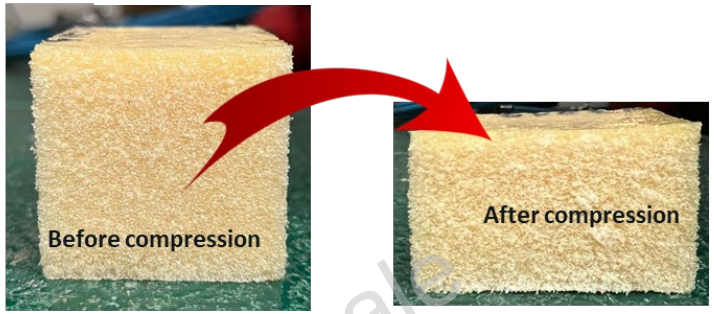
To simulate the fall of an artefact of 300 g from h~2 m

- ✓ Impact energy = 5J
- ✓ Velocity = 1 m/s.
- ✓ Samples= cubic shape, 30 mm edge (⊥; ‖ to the foam grow direction)

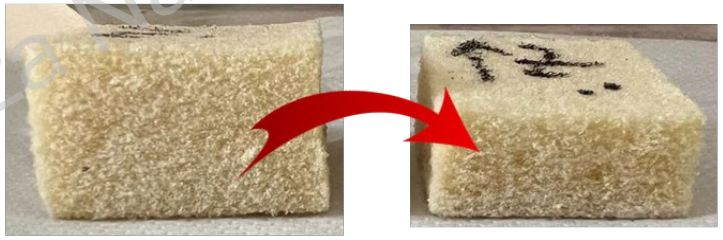
Nazionale

Cycles mechanical test

Pristine



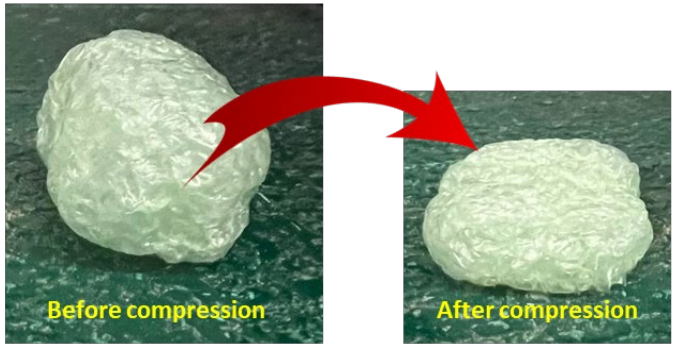
Composite



Before compression

After compression

Conventional pack



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Thank you

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