Associazione Nazionale Poliuretano Espanso rigido

2026 PU

MICS
Made in Italy
Circolare e Sostenibile

UNIVERSITÀ DEGLI STUDI DI PADOVA

From Textile Waste to Recycled Polyols for the Production of New Rigid PU Foams

Supervisor: Prof. Michele Modesti

Co-supervisor: Prof. Alessandra Lorenzetti

PhD student: *Diego Penzo*

XXXVIII cycle – III year

Presentation lineup

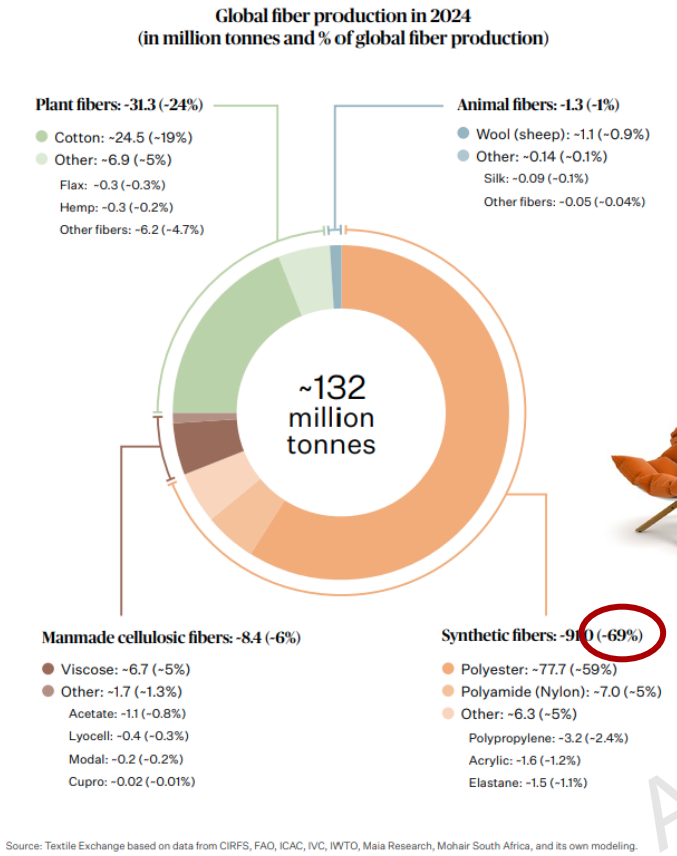
- **Goal of the project**

- **Activities of these three years**
  - Chemical recycling of PET-PU flexible
  - Deamination step
  - Chemical recycling of PET-PU fiber
  - Chemical recycling of textiles based on PET-PU-PA
  - Period Abroad: Chemical recycling of Nylon (PA)

- **Future research**

- **Additional activities**

Goal of the project



CHEMICAL RECYCLING OF SYNTHETIC TEXTILE

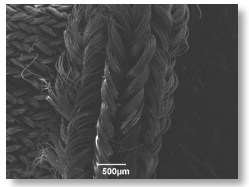
↓

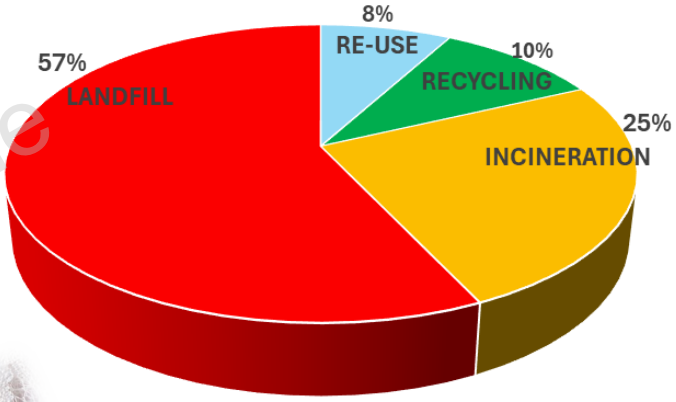
PET - PU

PA

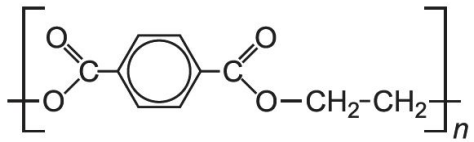
PU - flexible foam

PU - fibers

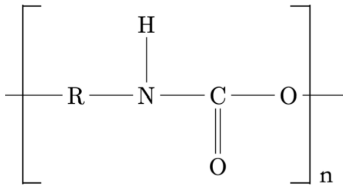




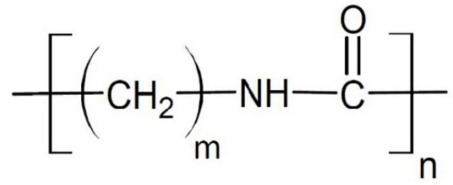
Polyethylene terephthalate (PET)



Polyurethane (PU)



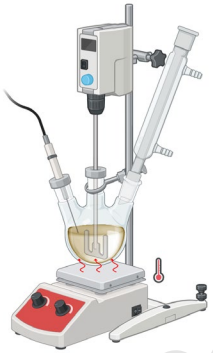
Polyamide (PA)



Goal of the project

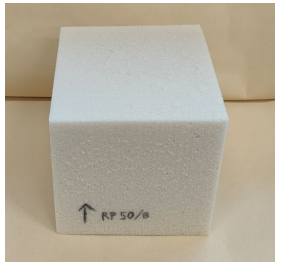
CHEMICAL RECYCLING OF SYNTHETIC TEXTILE

Waste Collection

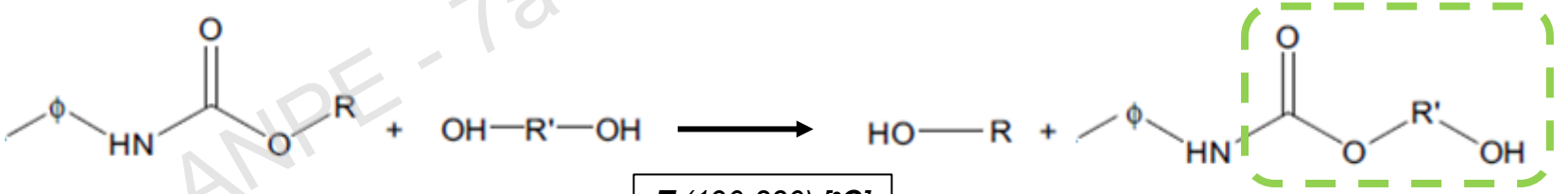


Glycolysis

Polyol

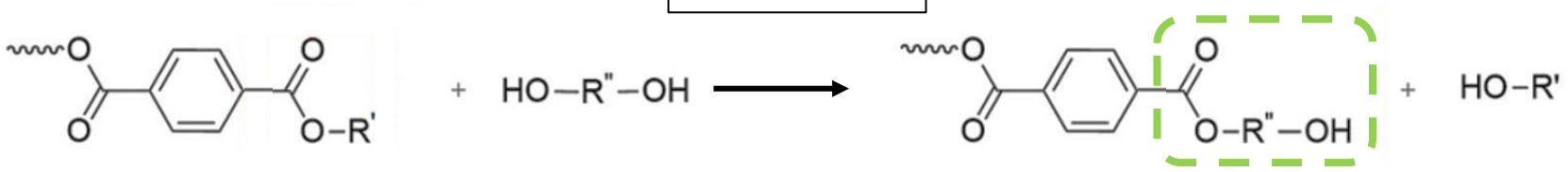


New PU foams

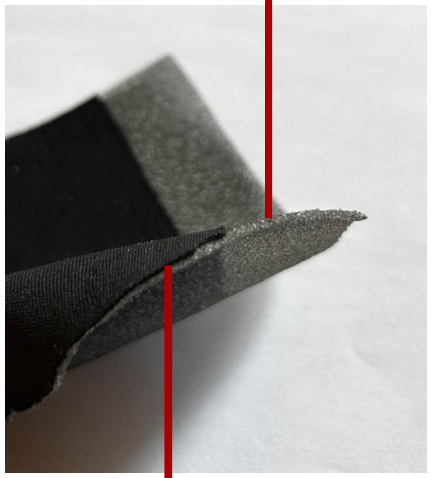


PU & PET ***GLYCOL*** ***POLYOLS***

T *(190-230) [°C]*
t *(1-4) [h]*
Cat.



Chemical recycling of PET-PU flexible



PU

PET

DoE

Variables

% Polyol/waste (50/50 – 40/60)

% PU (10% – 30% – 50%)

Temperature (200 °C – 220 °C)

Constant

Catalyst amount;

Type of material;

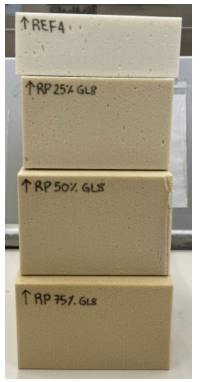
Combined PET-PU

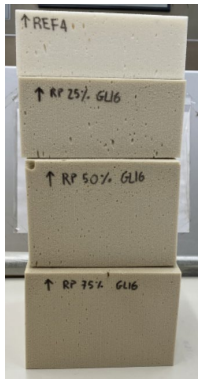
For RIGID FOAM

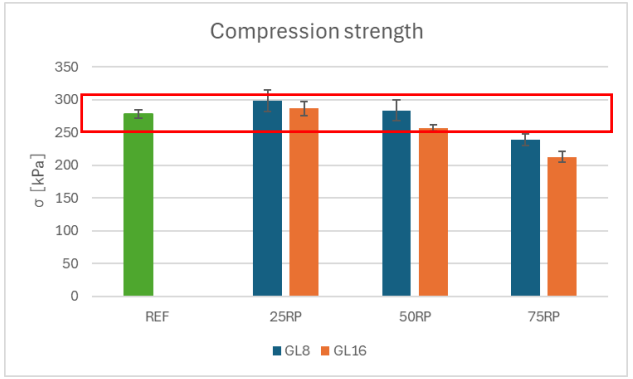
400 – 500 mg_{KOH}/g_{sample}

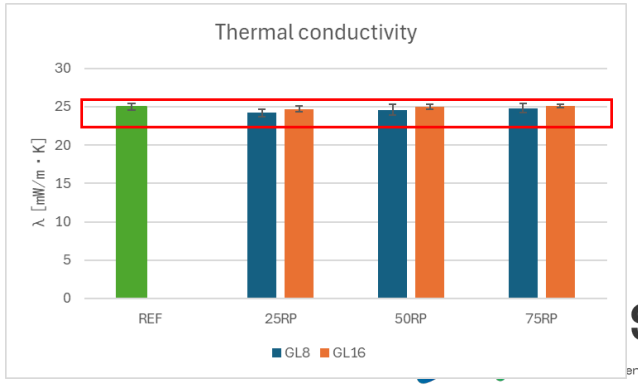
< 8000 cP

< 1000 ppm **D**

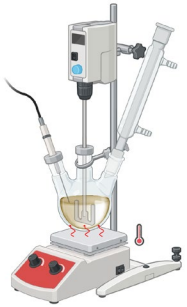


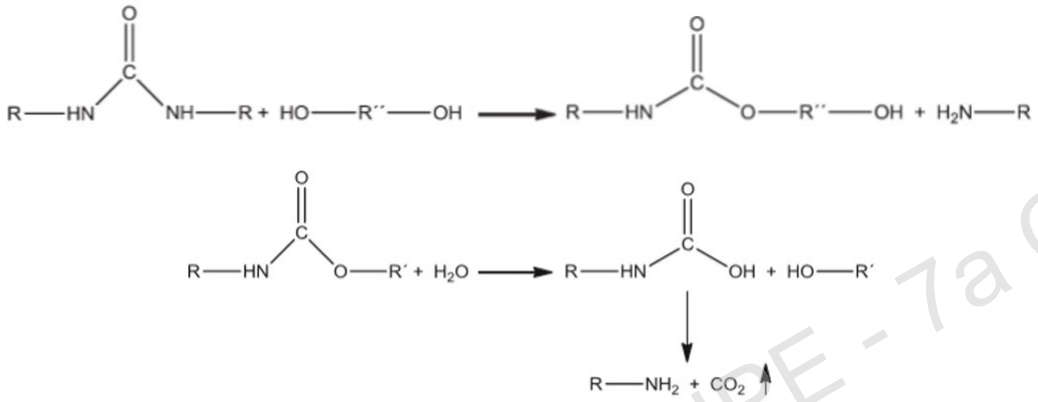


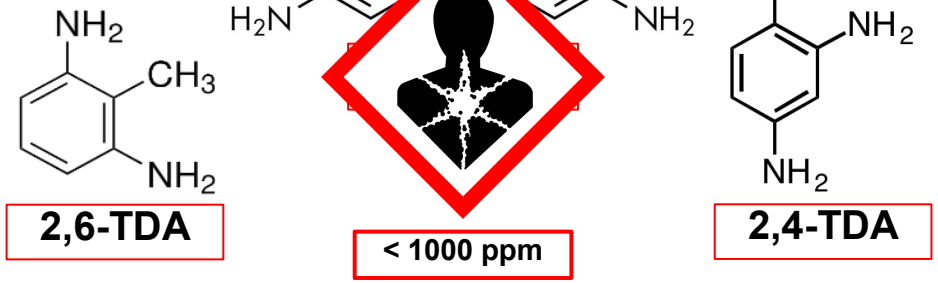




Deamination step





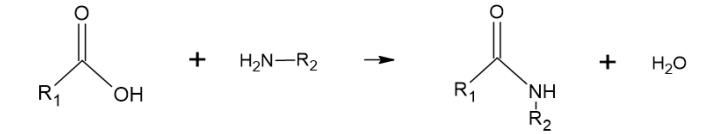


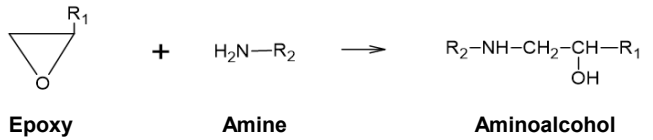
Deaminating agents

Carboxylic acids

BIOPOL®

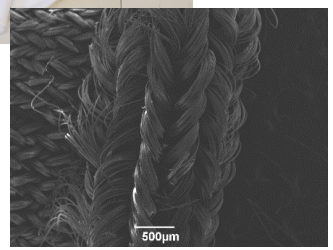
Epoxy compounds

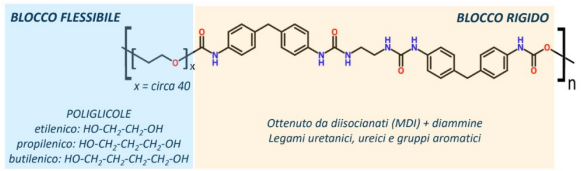




	Stearic acid	Succinic acid	BIOPOL®	Epoxy compounds
Aromatic Amines content	✗	✓	✓	✓
Selectivity	✗	✗	✗	✓
Vicosity	✗	✗	✗	✓

Chemical recycling of PET-PU fibers



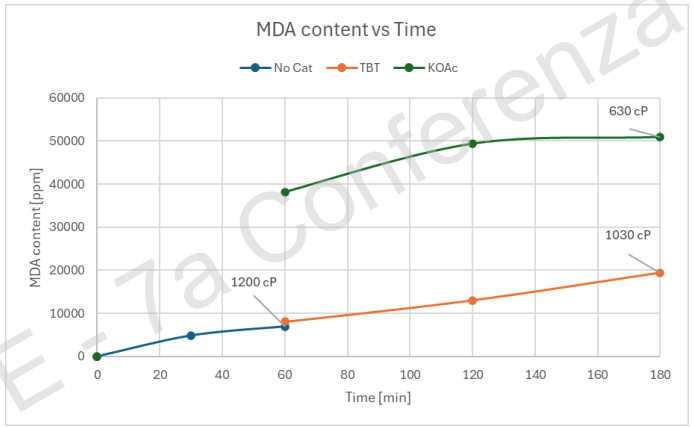


Glycolysis of Spandex

Temperature (210-220 °C)

Time (1-2 h)

Cat~~a~~lysts

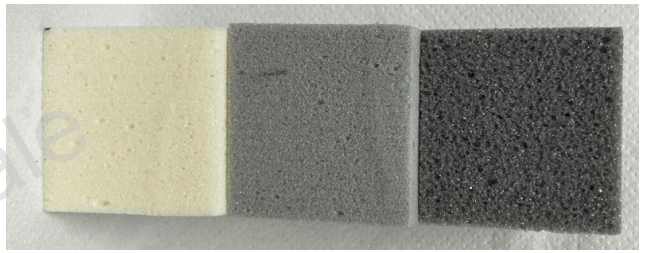


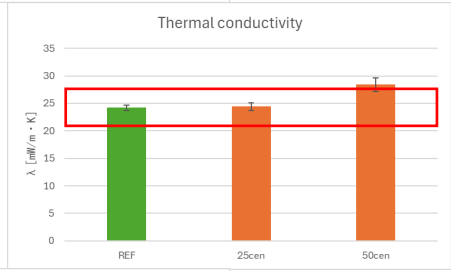
Lower reaction time

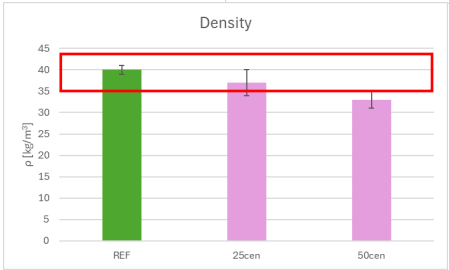
Lower MDA content

Similar Viscosity

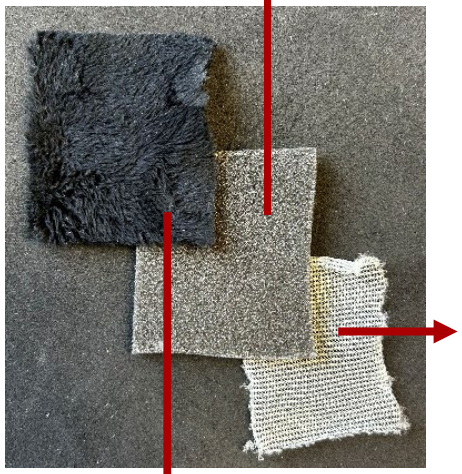
D







Chemical recycling of PET-PU-PA

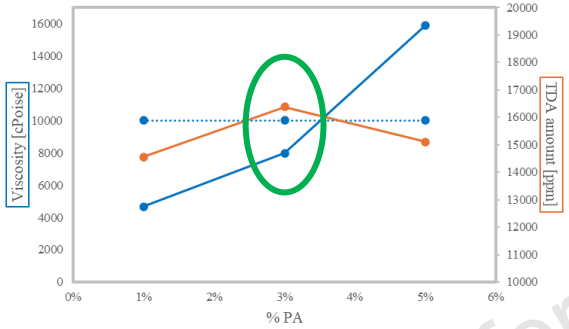


PU

PA

PET

% PA



Combined PET-PU-PA

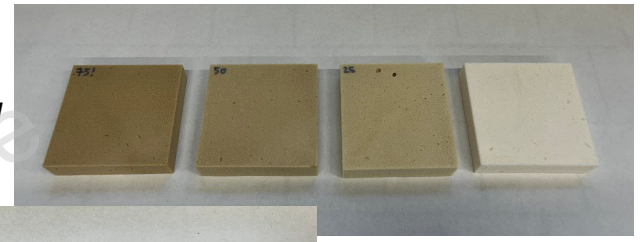
For RIGID FOAM

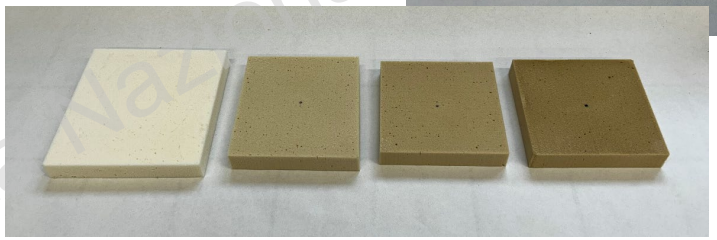
400 – 500 mg_{KOH}/g_{sample}

< 8000 cP

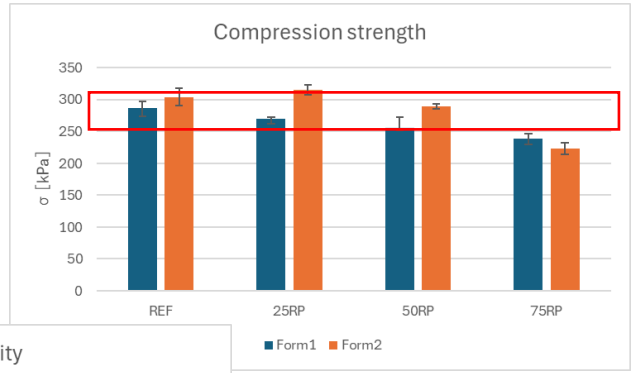
< 1000 ppm **D**

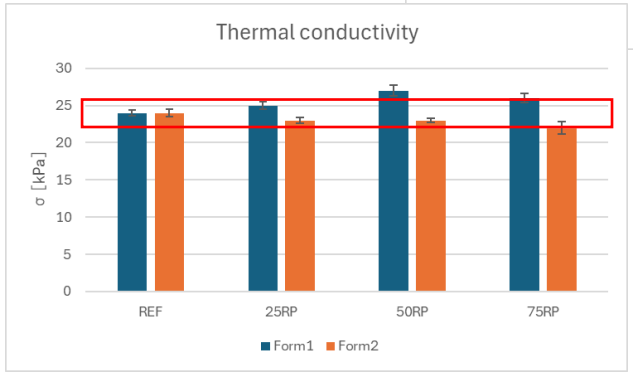
Form1





Form2





CHEMICAL RECYCLING OF POLYAMIDE

DoE Conditions

Temperature (180-190-200) [°C]

Time (4-5-6) [h]

Acid/PA Ratio (0,5-1-1,5)

ACIDOLYSIS of PA

PET-PU-PA SEPARATION

Different acids

Adipic Acid

Succinic Acid

Sebacic Acid

Gallic Acid

Terephthalic Acid

Aspartic Acid

Glutaric Acid

Future research

- **Glycolysis tests** using other combined textile waste systems;
- Try to treat textiles with **other solvolysis processes** (acidolysis, aminolysis);
- **LCA** and economical analysis;
- **<u>Pilot plant scale test.</u>**

Additional activities

- **Publications**
  - Donadini R.; Boaretti C.; Lorenzetti A.; Roso M.; **Penzo D**.; Dal Lago E.; Modesti M.; *Chemical Recycling of Polyurethane Waste via a Microwave-Assisted Glycolysis Process*; ACS Omega 2023, 8, 4655-4666
  - Donadini R.; Roso M.; Covassin A.; **Penzo D**.; Del Bianco G.; Romagnano S.; Modesti M.; *Closing the Loop of Polyurethane Adhesives: 2 Acidolysis Process Optimization;* SSRN 31/12/2023 http://dx.doi.org/10.2139/ssrn.4680375
  - Zanatta S.; Boaretti C.; Dal Lago E.; Scopel L.; **Penzo D**.; Modesti M.; *Mechanical Recycling of Post-Industrial PC/ABS Blends from the Automotive Sector by Mixture Design;* Processes 2024, 12, 349 https://doi.org/10.3390/pr12020349
  - Todesco M.; Luisetto R.; Casarin M.; Simoni E.; **Penzo D**.; Sandrin D.; Modesti M.; Astolfi L.; Albertin G.; Romanato F.; Marchesan M.; Gerosa G.; Fontanella C.; Bagno A. *In vitro assessment and preliminary in vivo characterization of innovative hybrid materials for biomedical applications*. Manuscript number: JBMR-A-25-0036.R2; Journal: Journal of Biomedical Materials Research: Part A; March 2025
  - N. Gama*, **D. Penzo**, B. Godinho, M. Modesti, A. Ferreira, A. Lorenzetti, A. Barros-Timmons.; *Rethinking Nylon Recycling: A Novel Chemical Approach for Sustainable Polyamide Recycling*. Journal of Environmental Chemical Engineering, December 2025
  - N. Gama*, **D. Penzo**, B. Godinho, M. Modesti, A. Ferreira, A. Lorenzetti, A. Barros-Timmons.; *Statistical Evaluation of Nylon Chemical Recycling through Acidolysis.* Polymer International, May 2026
- **Oral presentation**
  - **Penzo D**.; Zamuner A.; Dettin M.; Rossignolo G.; Modesti M.; Roso M.; *Chitosan based electrospun material: regenerative properties in different biomedical fields;* 25-28 June 2024, Krakow, 8th International Conference on Electrospinning
  - **Penzo D**.; Modesti M.; *Development of innovative chemical processes for the recycling of synthetic textiles*; 14-17 September 2025, Ischia (NA), Italy, GRICU 2025
- **Poster session**
  - **Penzo D**.; Bombarda F.; Modesti M.; *Solvolysis of polyesters sport-textiles wastes combined with polyurethane fibers*. 11-13 June 2025, Dresden. AUTEX 2025 World Conference
- **Round Table**
  - **Penzo D**.; Di Girolamo R.; Modesti M.; Fiorotto N.; Previero D.; *Circolarità delle materie plastiche: riciclo chimico e riciclo meccanico.* Made in Italy Innovation Forum, Cernobbio (CO), Giugno 2025, MICS – Italian PNRR – M4 C2, Invest 1.3 D.D. 1551.11-10-2022, PE00000004
- **Tutor activities**
  - "Industrial Chemical Processes II", prof. Modesti Michele, A.A. 23/24, 24/25, 25/26

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