Increasing the sustainability of thermal insulation materials through mechanical reprocessing of polyurethane and phenolic foams

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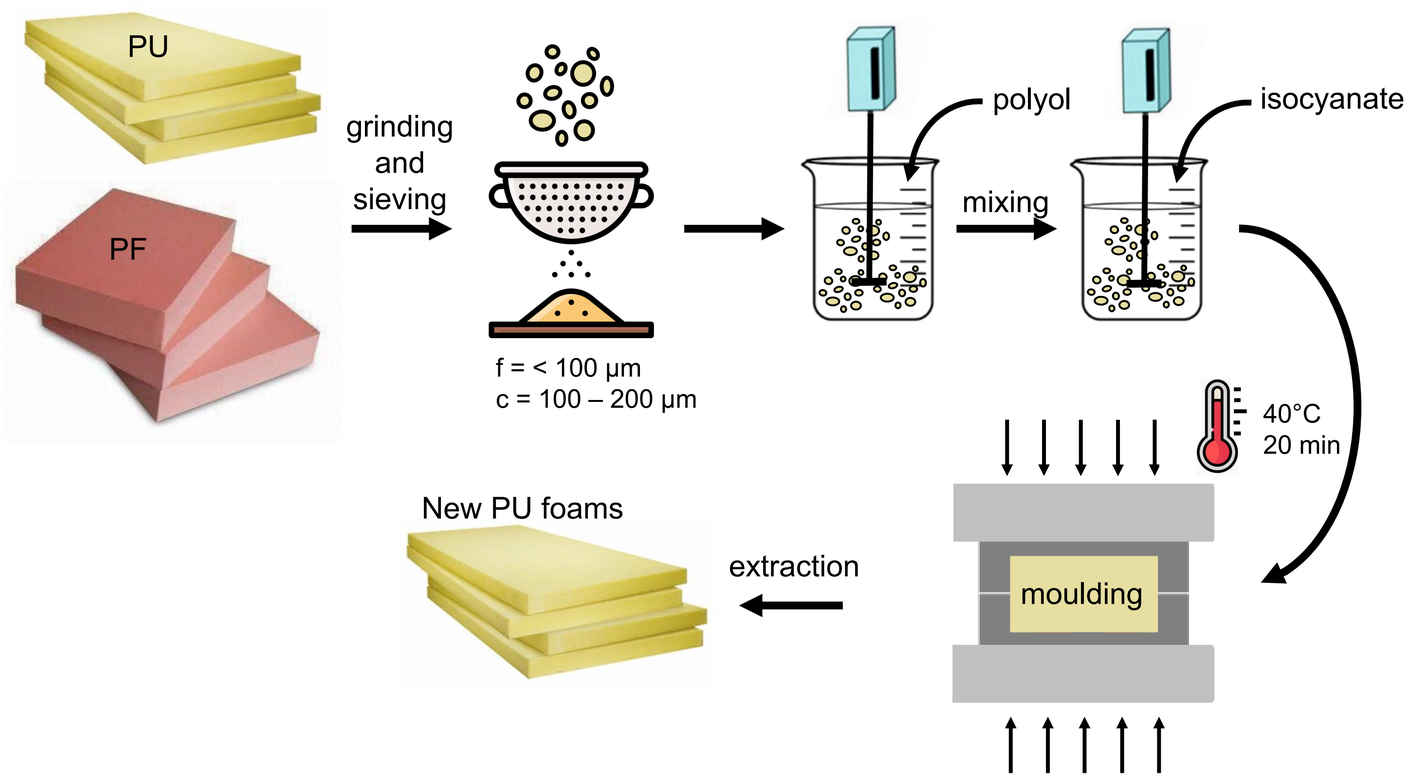
Introduction

- Polyurethane foams (**PU**) and phenolic resin foams (**PF**) are widely recognized for their exceptional insulating properties and have become the preferred choice for insulation applications in various sectors, including residential and commercial buildings, transportation, and the military.
- The intensification of their use has recently led to an increased need for responsible **end-of-life management**.

Aim of the work → reduce the use of virgin material and promote a circular re-utilization of recycled materials through **mechanical reprocessing**.

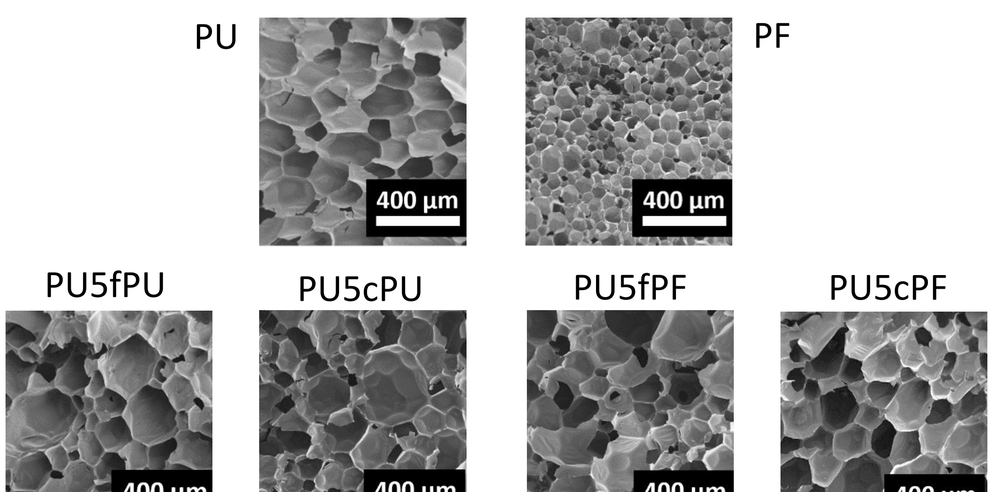
Sample preparation



Sample	PU virgin (% wt)	Granulometry of recyclate (µm)	PU recyclate (% wt)	PF recyclate (% wt)
PU	100.0	-	-	-
PF	0.0	-	-	-
PU2.5fPU	97.5	≤ 100	2.5	-
PU5fPU	95.0	≤ 100	5.0	-
PU7.5fPU	92.5	≤ 100	7.5	-
PU2.5cPU	97.5	100-200	2.5	-
PU5cPU	95.0	100-200	5.0	-
PU7.5cPU	92.5	100-200	7.5	-
PU2.5fPF	97.5	≤ 100	-	2.5
PU5fPF	95.0	≤ 100	-	5.0
PU7.5fPF	92.5	≤ 100	-	7.5
PU2.5cPF	97.5	100-200	-	2.5
PU5cPF	95.0	100-200	-	5.0
PU7.5cPF	92.5	100-200	-	7.5

Results

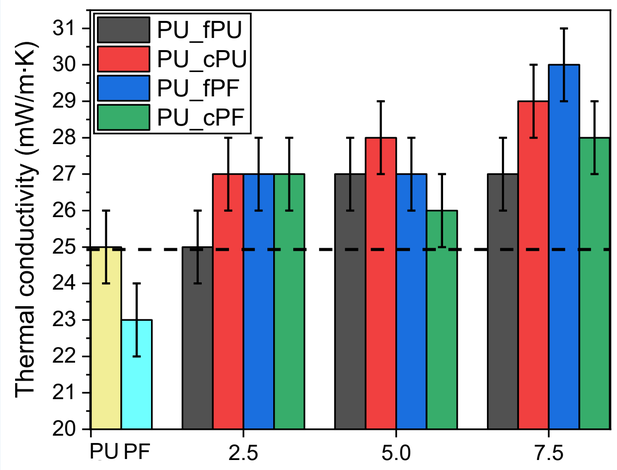
MORPHOLOGICAL ANALYSIS (FESEM)



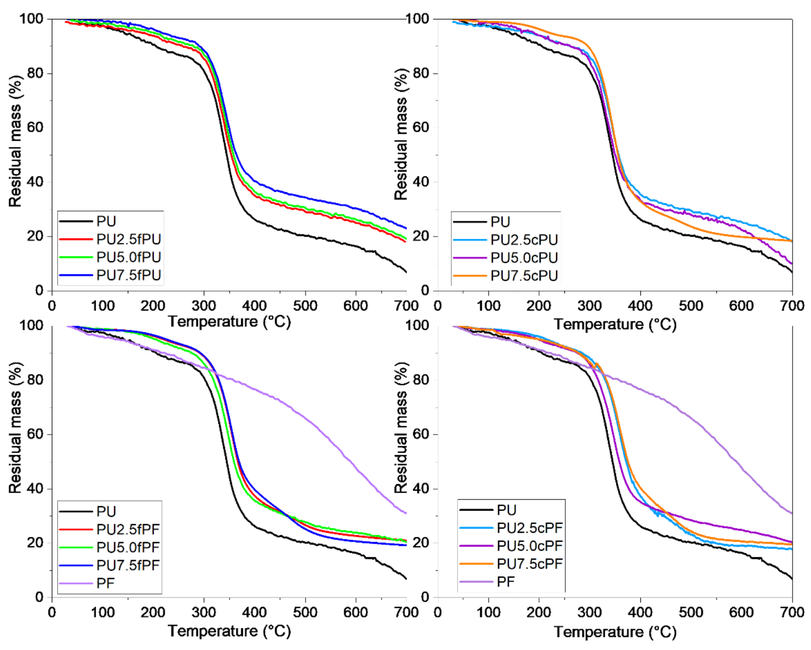
DENSITY AND POROSITY

Sample	ρ_{geom} (g/cm³)	P_{closed} (%)
PU	0.044 ± 0.003	47.4 ± 2.0
PF	0.035 ± 0.003	-
PU2.5fPU	0.057 ± 0.006	25.8 ± 2.5
PU5fPU	0.062 ± 0.015	15.4 ± 0.2
PU7.5fPU	0.059 ± 0.001	12.6 ± 1.5
PU2.5cPU	0.049 ± 0.001	24.9 ± 1.1
PU5cPU	0.048 ± 0.004	19.7 ± 1.1
PU7.5cPU	0.058 ± 0.009	35.4 ± 1.1
PU2.5fPF	0.055 ± 0.010	1.2 ± 1.1
PU5fPF	0.048 ± 0.003	2.6 ± 0.2
PU7.5fPF	0.050 ± 0.002	1.1 ± 0.2
PU2.5cPF	0.052 ± 0.007	7.4 ± 0.1
PU5cPF	0.055 ± 0.001	10.1 ± 0.1
PU7.5cPF	0.059 ± 0.013	2.1 ± 1.5

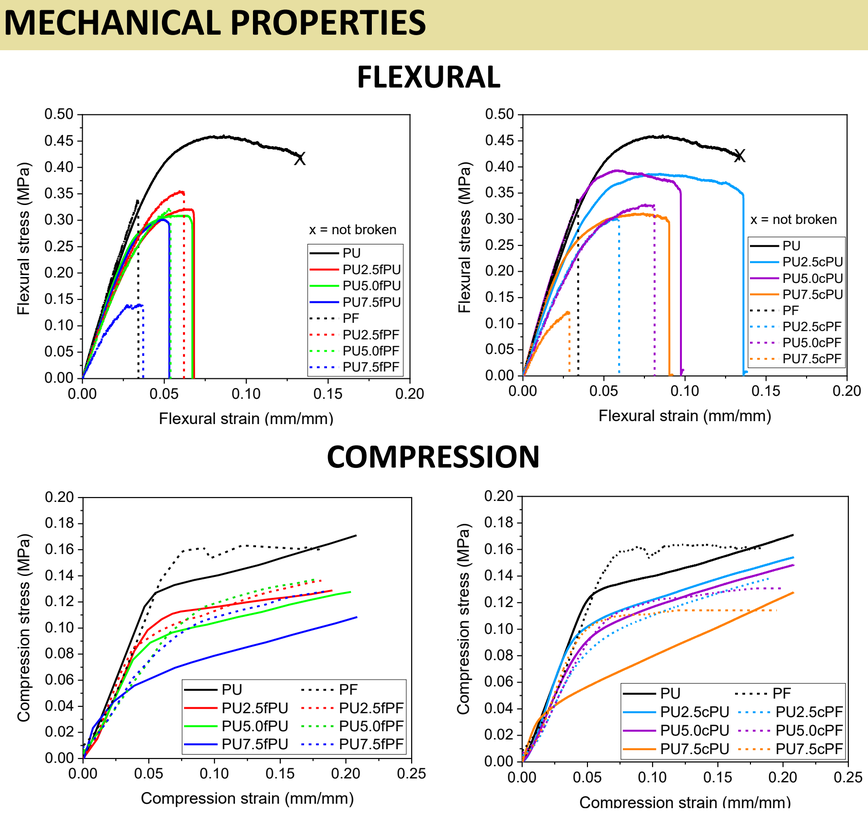
THERMAL CONDUCTIVITY



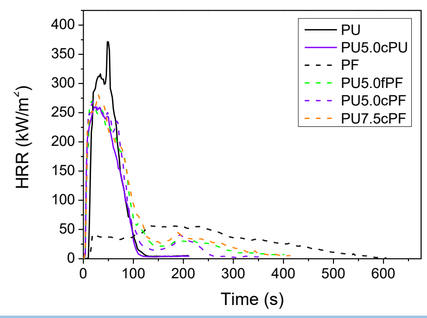
THERMOGRAVIMETRIC ANALYSIS



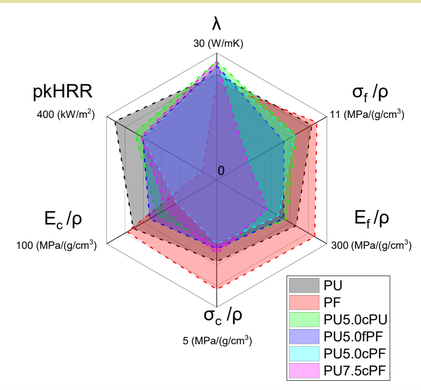
MECHANICAL PROPERTIES



CONE CALORIMETRY



COMPARSION OF PROPERTIES



Conclusions

- New PU formulations revealed a **consistent cell structure**.
- The incorporation of PU/PF recyclates in PU → increase foam density and thermal conductivity, decrease in closed porosity, but still **good thermal insulation** power.
- PF/PU recyclates decrease mechanical properties, but improve thermal stability and **fire safety** of foams.

FULL PAPER