POZNAN UNIVERSITY OF TECHNOLOGY

MANUFACTURING 2024

FACULTY OF MECHANICAL ENGINEERING

MANUFACTURING

14-16.05.2024. POZNAŃ. POLAND

International Scientific-Technical Conference

Title:

Upcycling furniture polyurethane foam wastes

Author/Authors:

Aleksander HEJNA[1], Mateusz BARCZEWSKI[1], Joanna ANIŚKO[1], Adam PIASECKI[1], Paulina KOSMELA[2]

[1]Poznan University of Technology. POLAND; [2]Gdańsk University of Technology. POLAND

aleksander.hejna@put.poznan.pl

Upcycling furniture polyurethane foam wastes

INNOGOW - Supporting innovation in bulky waste management

(Science for the Society II. NdS-II/SP/0039/2024/01)

Principal Investigator: dr inż. Aleksander Hejna

Funding: PLN 1.063.700.00

Flexible polyurethane foam wastes – origin and challenges

Production waste

- Market size of PU foams exceeds USD 50 billion (2023).
  - Projected CAGR ~6.5% until 2030.
- Production volume exceeds 12.5 million tons.
- Flexible foams account for ~48.5% of market.

Municipal bulky waste

- 13.7 million tons of municipal waste in Poland in 2021.
  - 2.8 million tons more than in 2015.
- Only 40% of selective collection.
- Mainly attributed to the waste furniture.

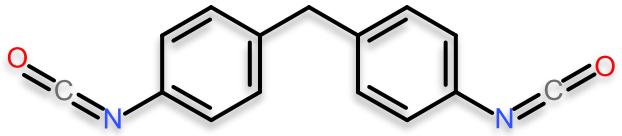
Applied raw materials

Two types of flexible PU foams obtained from commercially available and widely applied in industry PU systems:

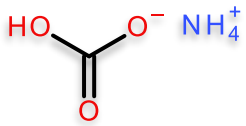
- unfilled foam without any functional additives,
- composite foam containing 5 parts per 100 parts of polyol (php) of waste rubber and 15 php of organophosphorous flame retardants,

→ passed through 2.8 mm sieve

- methylene diphenyl diisocyanate (MDI),



- ammonium bicarbonate (AB),



→
- MDI alone or MDI:AB 1:1 mass ratio
- 5, 10, or 15 wt% loading

Chemical rationale for the applied binder compositions

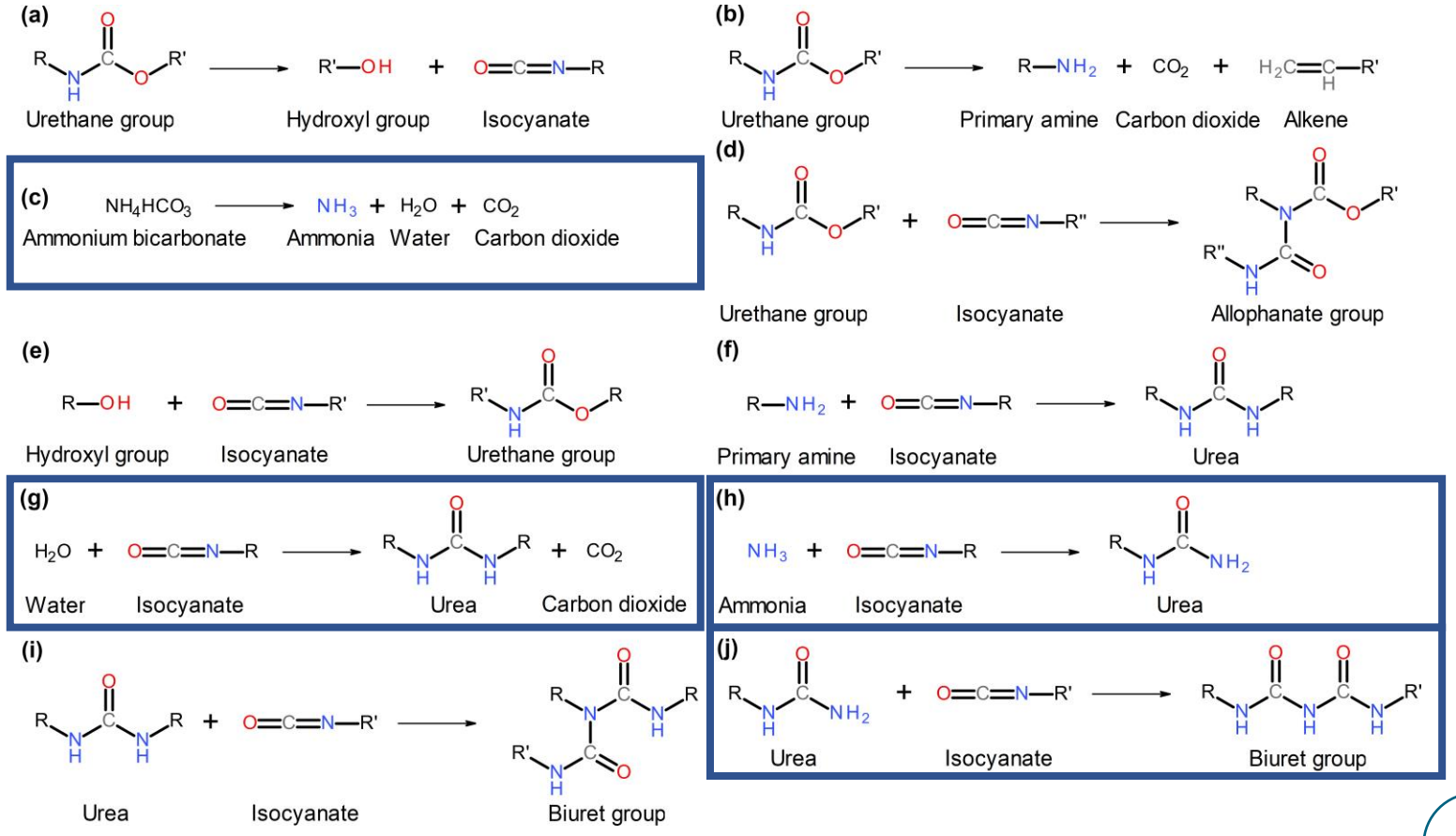
(a) and **(b)** – main decomposition mechanisms of urethane groups

(c) – ammonium bicarbonate thermal decomposition

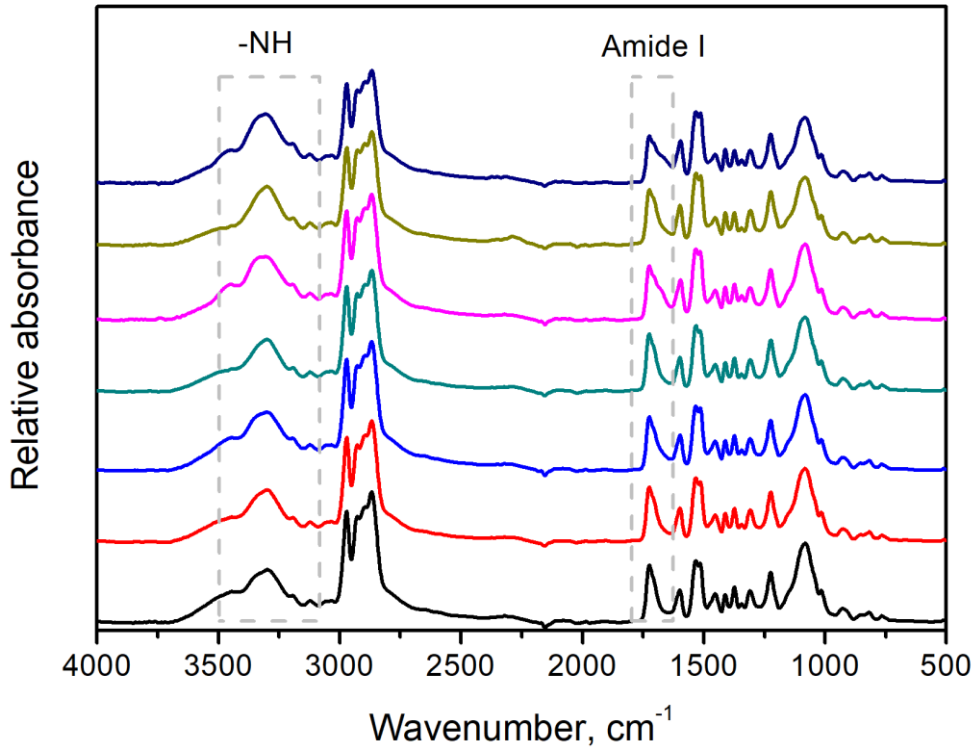
(d)-(f) – reactions between diisocyanate and PU decomposition products

(g) and **(h)** – reactions between binder components

(i) and **(j)** – additional crosslinking reactions

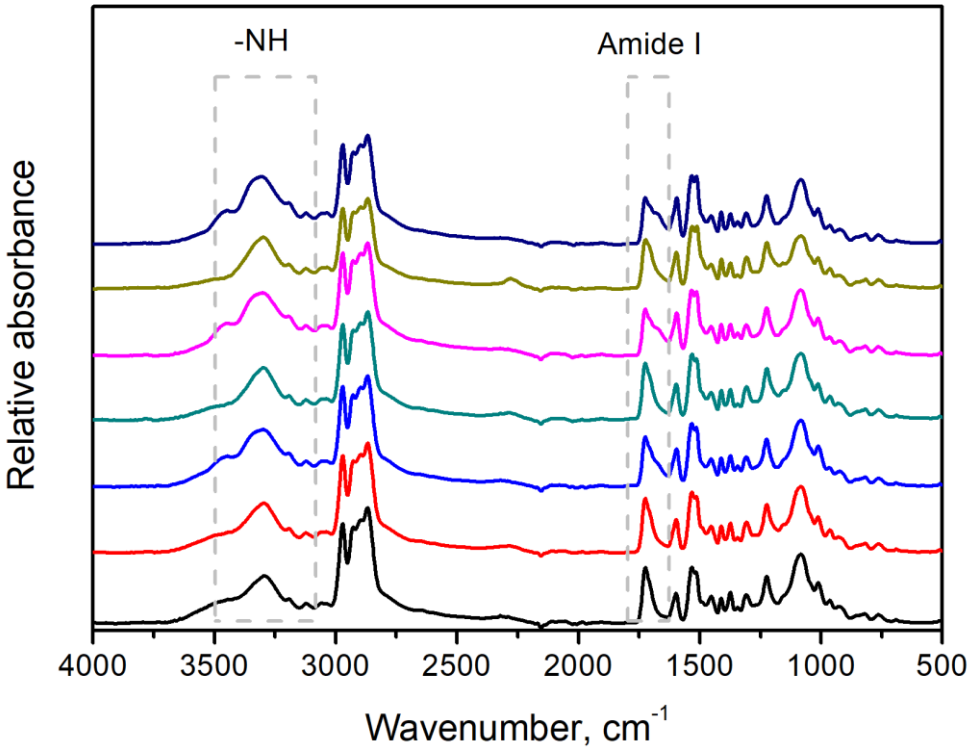


Chemical structure of prepared materials



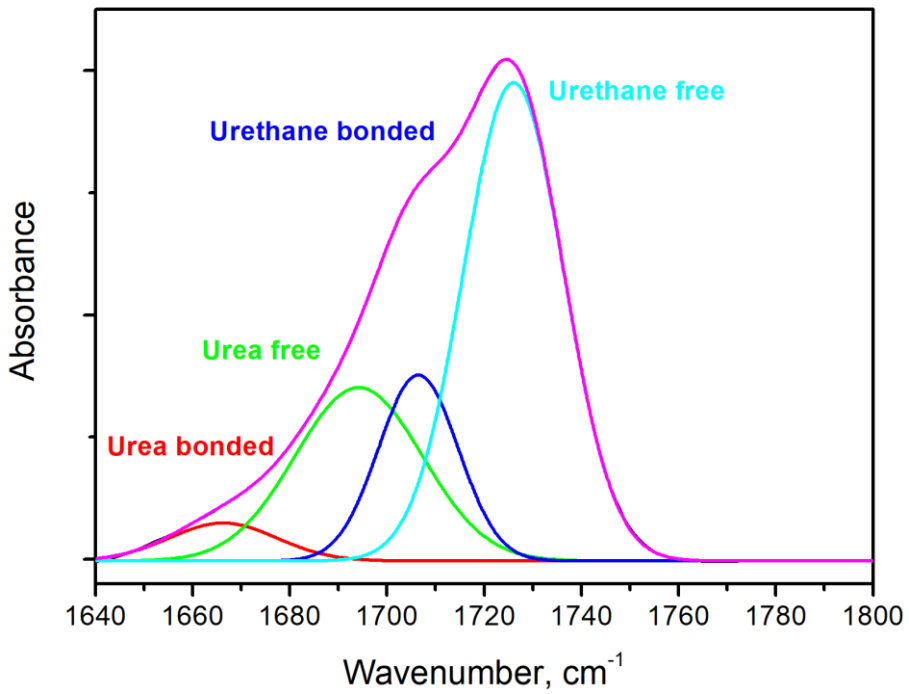
Unfilled foam

MDI/AB$_{15\%}$
MDI$_{15\%}$
MDI/AB$_{10\%}$
MDI$_{10\%}$
MDI/AB$_{5\%}$
MDI$_{5\%}$
Neat foam



Composite foam

Chemical structure of prepared materials

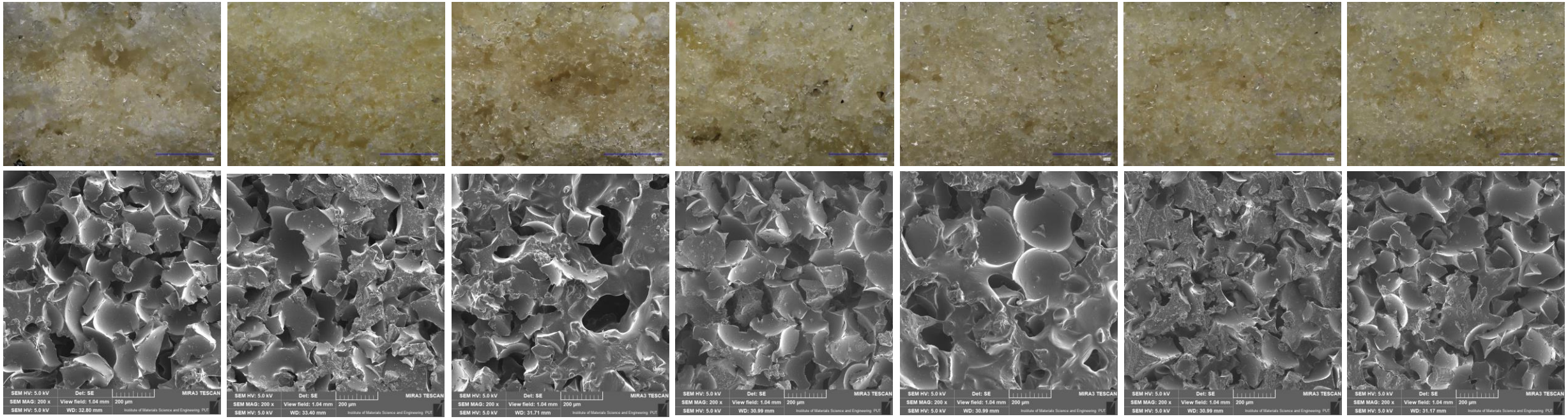


Sample	Unfilled foam			Composite foam		
	HBI	DPS	Urea fraction	HBI	DPS	Urea fraction
Neat foam	0.42	0.29	0.02	0.39	0.28	0.03
$MDI_{5\%}$	0.27	0.21	0.10	0.12	0.11	0.16
$MDI/AB_{5\%}$	0.48	0.32	0.04	0.43	0.30	0.17
$MDI_{10\%}$	0.57	0.36	0.03	1.63	0.62	0.17
$MDI/AB_{10\%}$	0.65	0.39	0.06	0.69	0.41	0.10
$MDI_{15\%}$	0.32	0.24	0.09	0.69	0.41	0.08
$MDI/AB_{15\%}$	0.42	0.29	0.12	0.37	0.27	0.11

Appearance of prepared materials

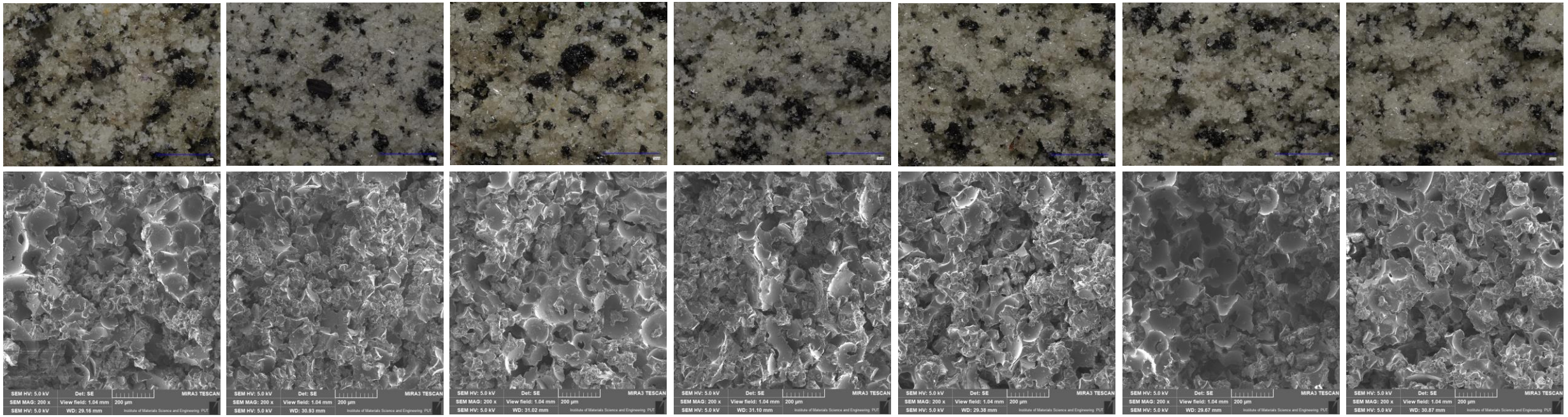
Neat foam | $MDI_{5\%}$ | $MDI/AB_{5\%}$ | $MDI_{10\%}$ | $MDI/AB_{10\%}$ | $MDI_{15\%}$ | $MDI/AB_{15\%}$

Morphology of prepared materials – unfilled foam



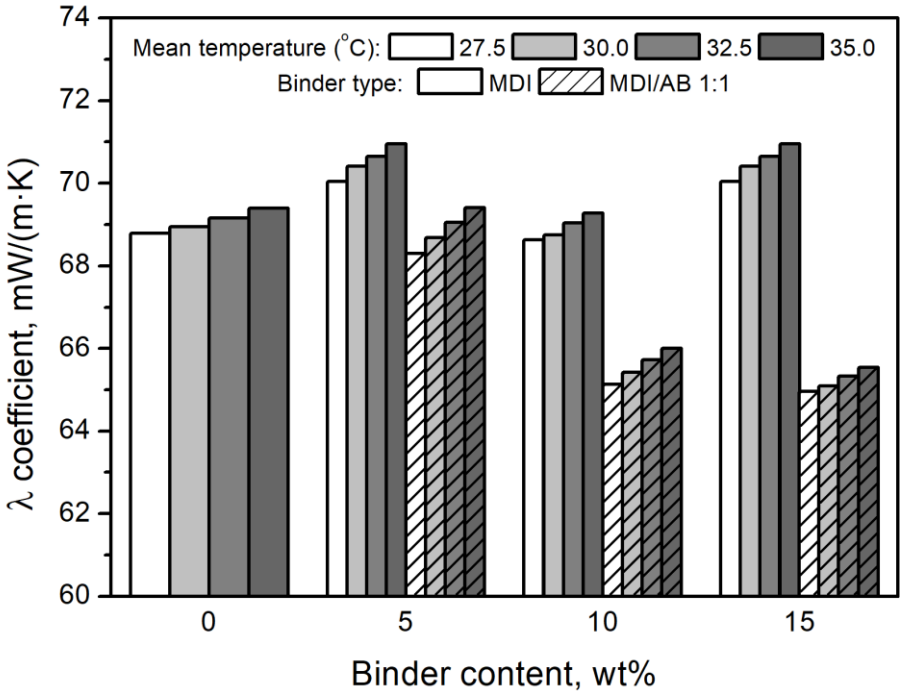
Neat foam | $MDI_{5\%}$ | $MDI/AB_{5\%}$ | $MDI_{10\%}$ | $MDI/AB_{10\%}$ | $MDI_{15\%}$ | $MDI/AB_{15\%}$

Morphology of prepared materials – composite foam

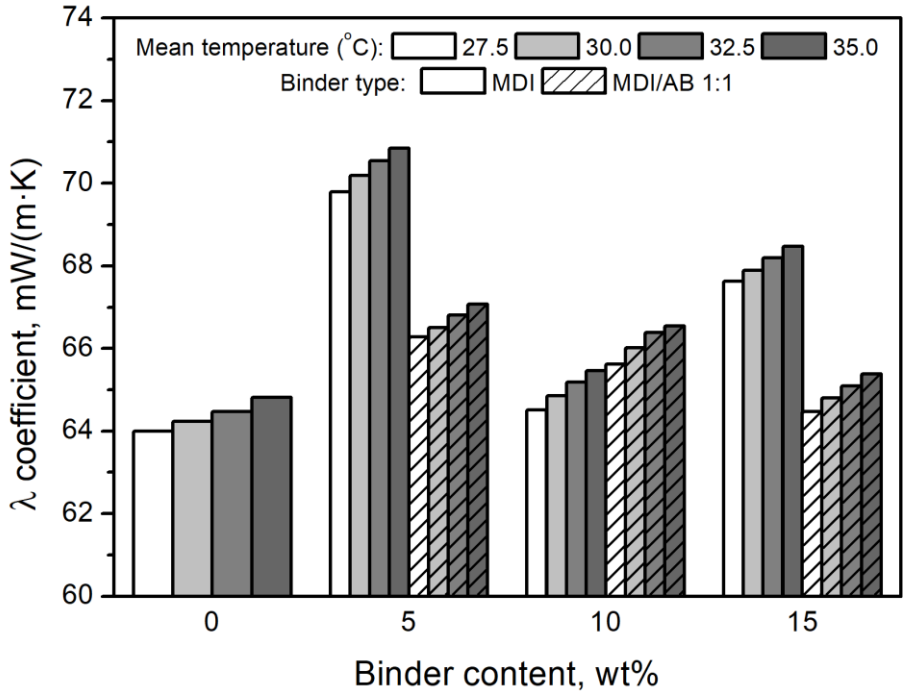


Neat foam | $MDI_{5\%}$ | $MDI/AB_{5\%}$ | $MDI_{10\%}$ | $MDI/AB_{10\%}$ | $MDI_{15\%}$ | $MDI/AB_{15\%}$

Insulation performance of prepared materials

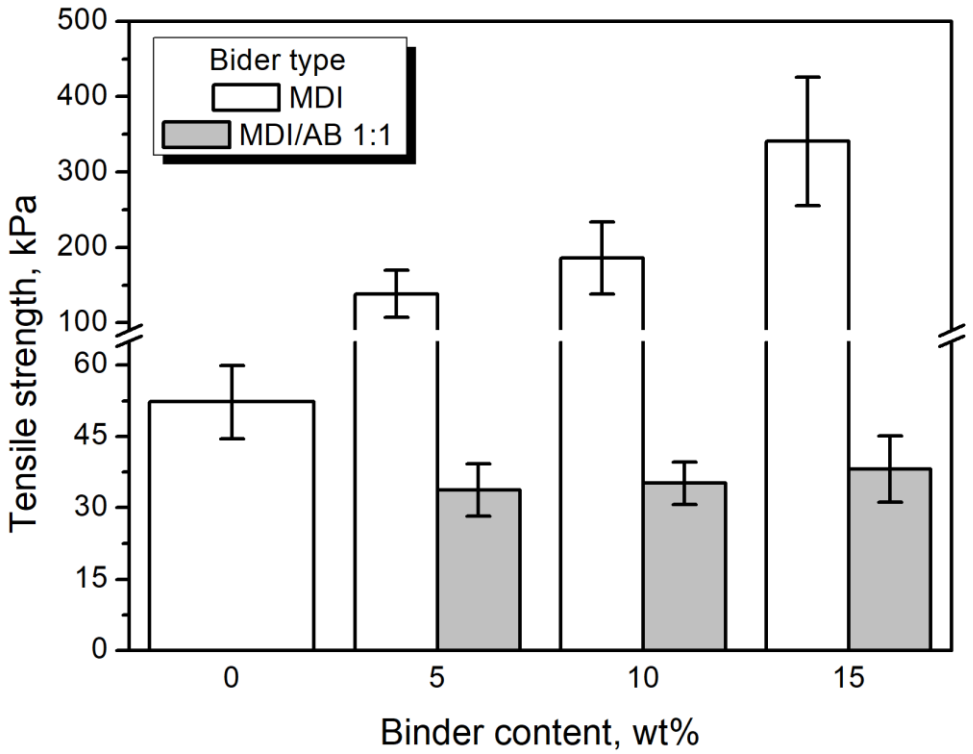


Unfilled foam

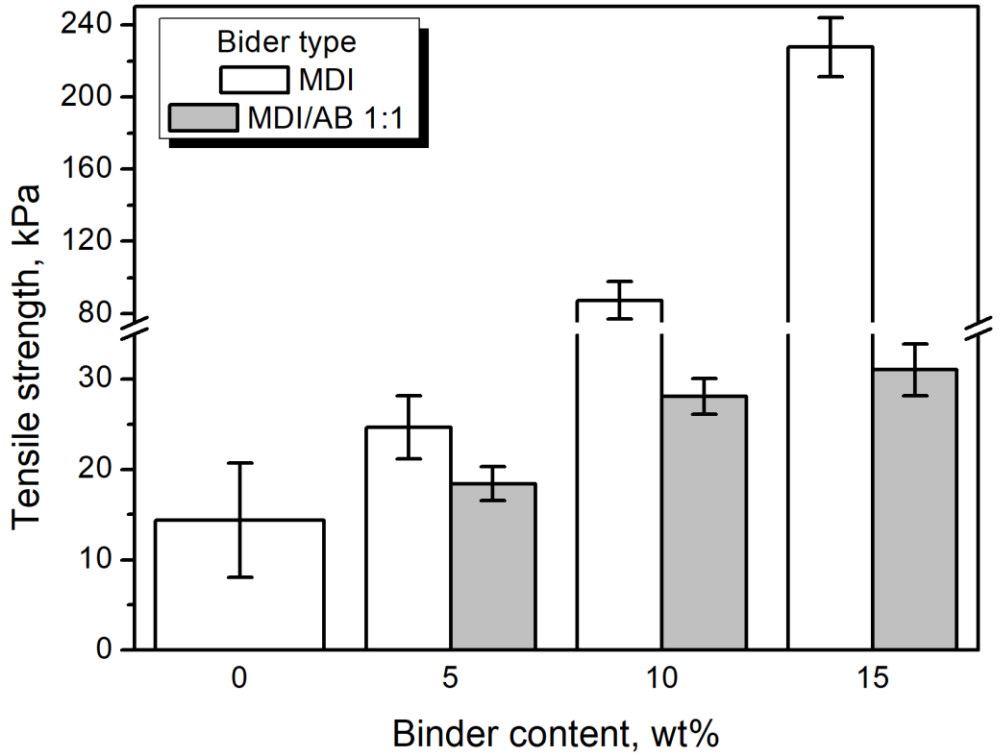


Composite foam

Mechanical properties of prepared materials

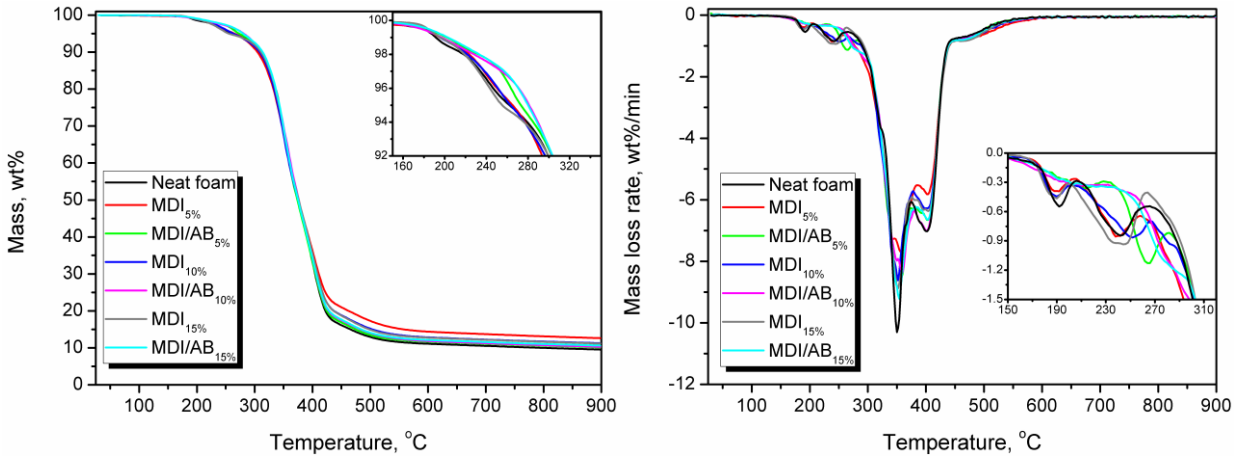


Unfilled foam

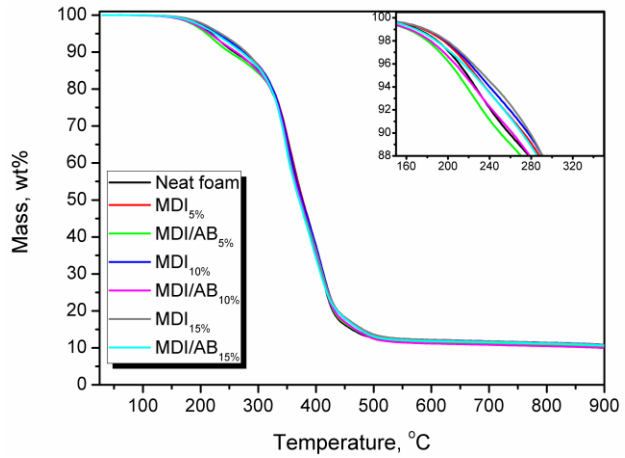


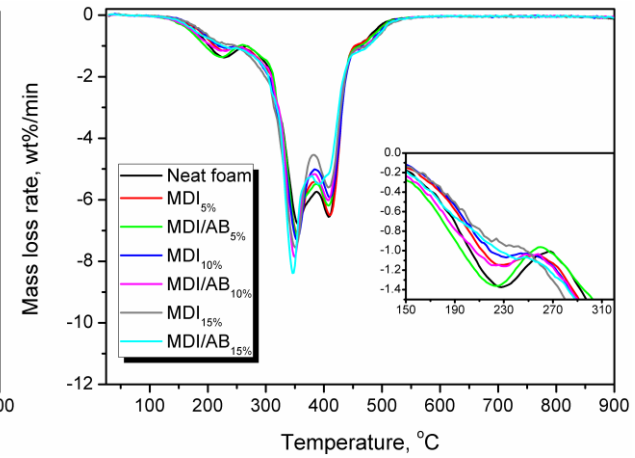
Composite foam

Thermal stability of prepared materials



Unfilled foam





Composite foam

Conclusions and future remarks

- Efficient recycling process with novel binder composition using simple process of compression molding,
- Reduced amount of conventionally applied diisocyanate required,
- Changes in the chemical interactions and resulting structure of final materials,
- PU phase decomposition extent driven by the MDI/AB ratio,
- Potential applications as waste-based binder for engineered wood materials,

POZNAN UNIVERSITY OF TECHNOLOGY

MANUFACTURING 2024

FACULTY OF MECHANICAL ENGINEERING

MANUFACTURING

14-16.05.2024. POZNAŃ. POLAND

International Scientific-Technical Conference