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Valorization of Cork Waste in Particleboard Production with Innovative Binder

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TECHNICAL UNIVERSITY IN ZVOLEN

INNOGOW - Supporting innovation in bulky waste management

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

Principal Investigator: dr inż. Aleksander Hejna

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Bulky wastes

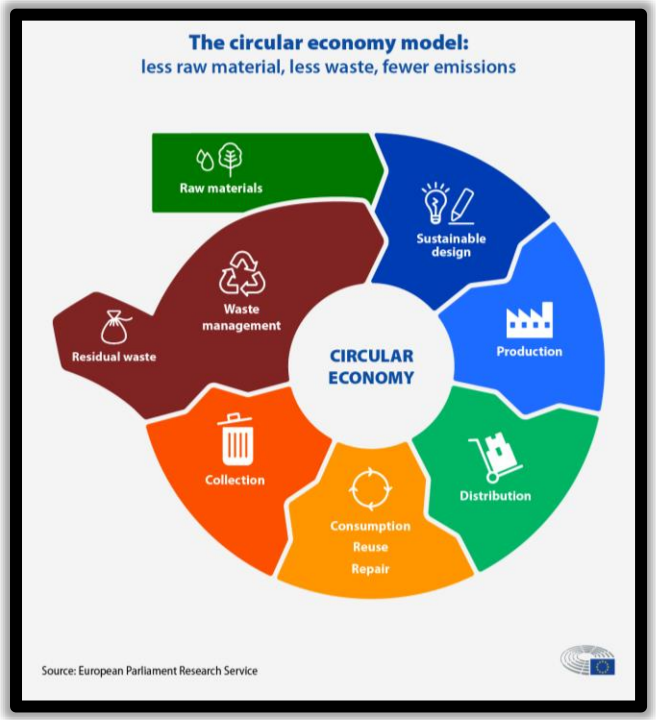
Basic information

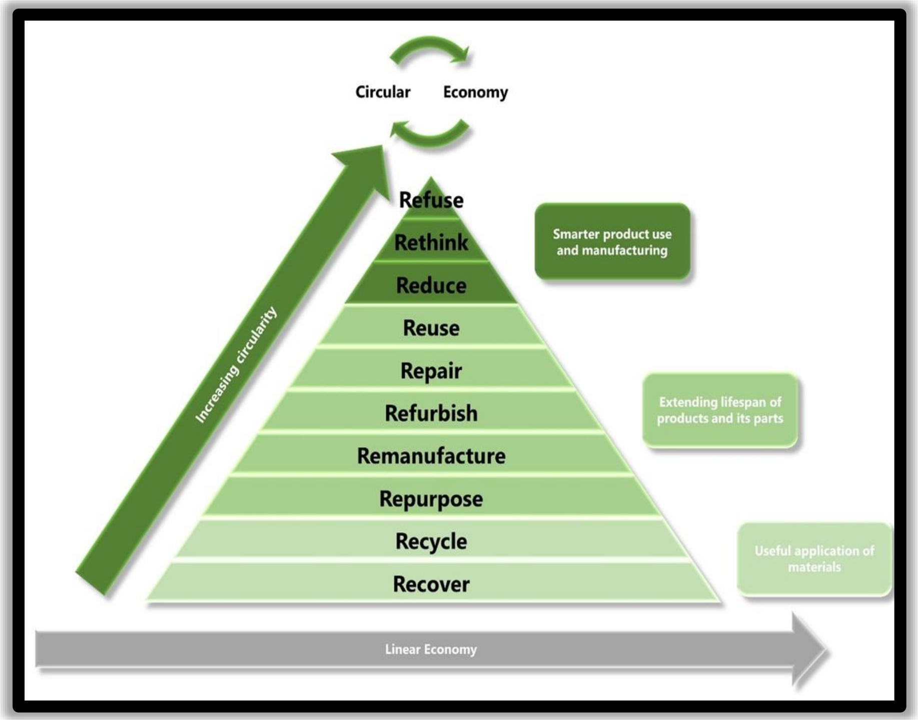
- Municipal waste generation in Poland (in million tons):

  10.9 (2015) → 13.7 (2021)
- Only 40% of recycling level
- Bulky waste – mainly wood, wood-based materials, and polyurethane foams
- Lack of efficient management methods and proper applications

Circular Economy

Motivation and measures





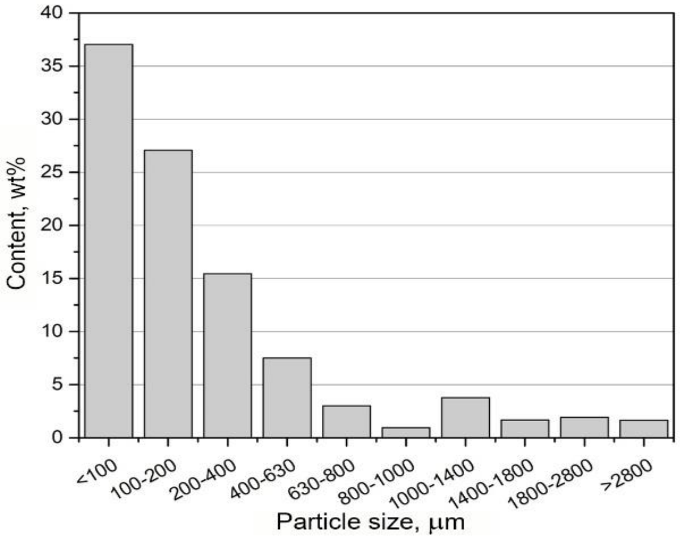
- EU Directives (Green Deal, Climate Target Plan)
- Penalties for not meeting targets
- Growing environmental awareness
- Need for novel waste management methods
- Need for final applications
- Need for high quality products

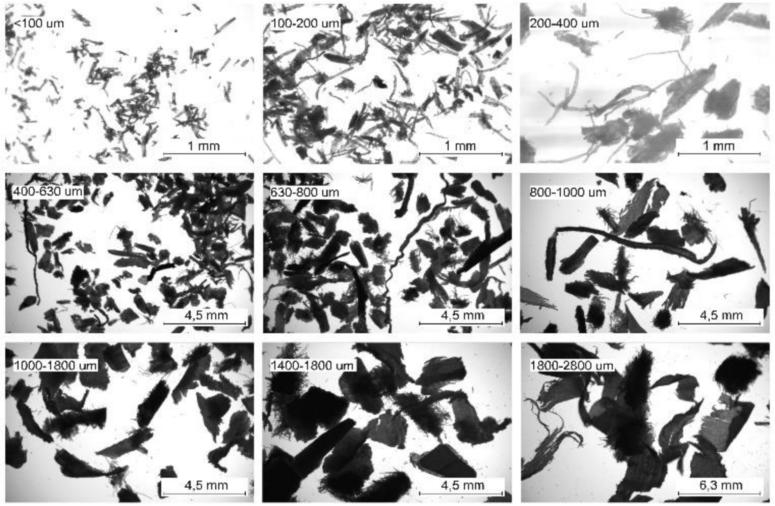
Materials

Wastes

Cork granulate (CORKPOL)

Fraction: 0.2-0.5 mm

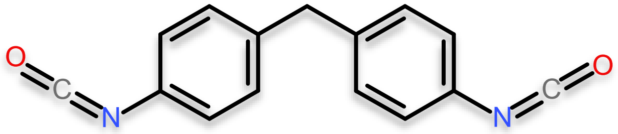


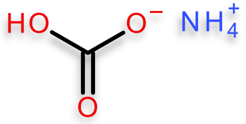


Binder

Methylene diphenyl diisocyanate (MDI)

Ammonium bicarbonate (AB)





Sample preparation

Applied compositions

Sample	Content, wt%		Binder composition, MDI:AB molar ratio	Molding temprature, °C	Molding time, min
	Cork	Binder			
1	80	20	1:0	100	2
2	80	20	3:1	100	2
3	80	20	2:1	100	2
4	80	20	1:1	100	2
5	80	20	1:2	100	2

Composites preparation

Sample preparation

Pre-mixing:

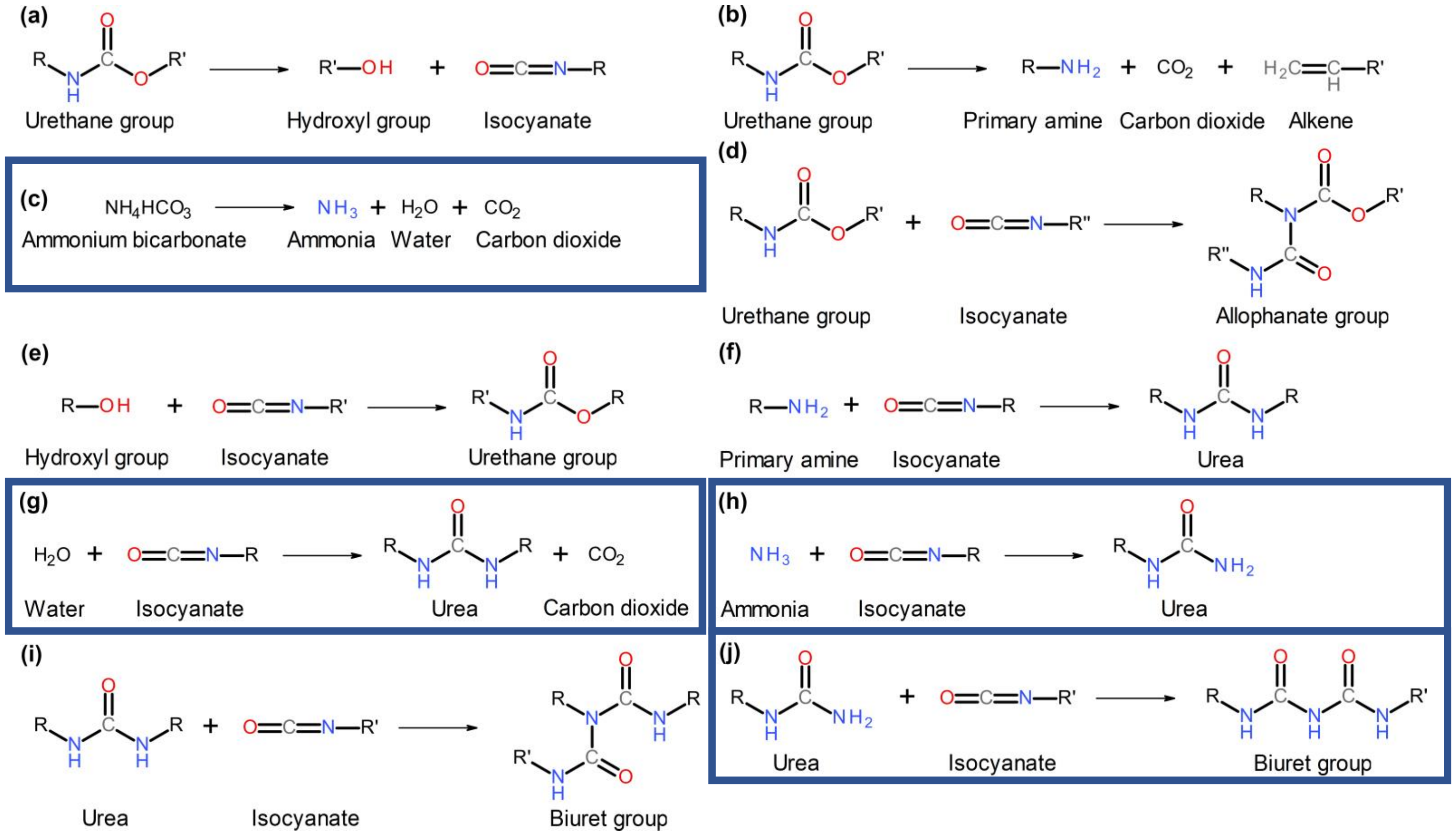
planetary mixer Gerlach GL 4219 (Germany),
5 minutes, ambient temperature

Compression molding:

Fontjine LabManual 300 (Netherlands),
2 minutes, 100 °C, 20 bar

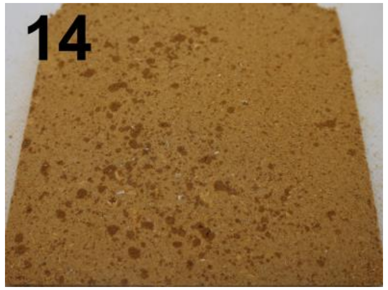
Sample preparation

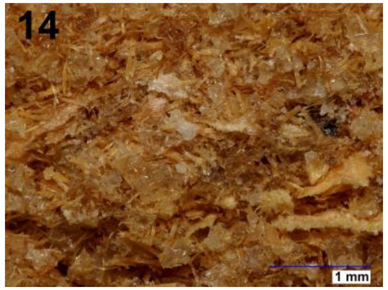
Chemical rationale for the applied binder compositions

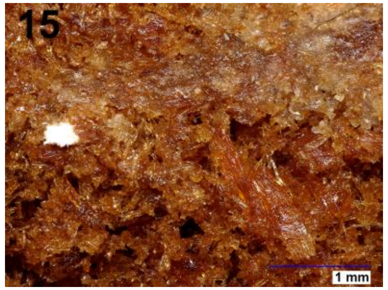


- **(a)** and **(b)** – main decomposition mechanisms of urethane groups
- **(c)** – ammonium bicarbonate thermal decomposition
- **(d)-(f)** – reactions between diisocyanate and PU decomposition products
- **(g)** and **(h)** – reactions between binder components
- **(i)** and **(j)** – additional crosslinking reactions

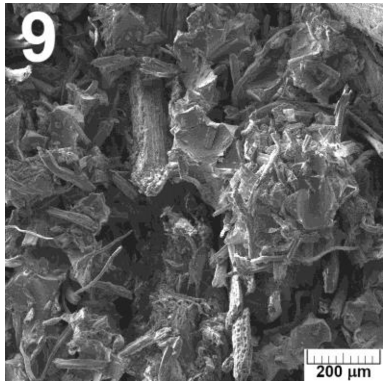
Composites appearance and morphology – different compression temperature

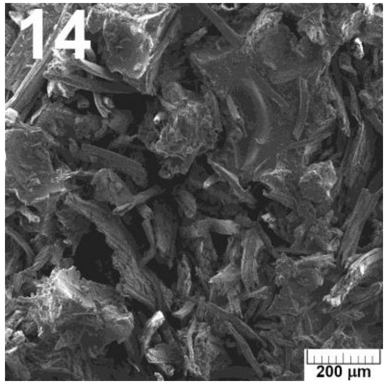


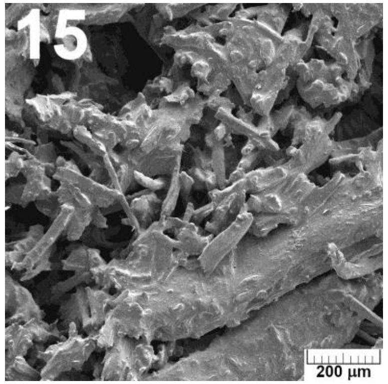




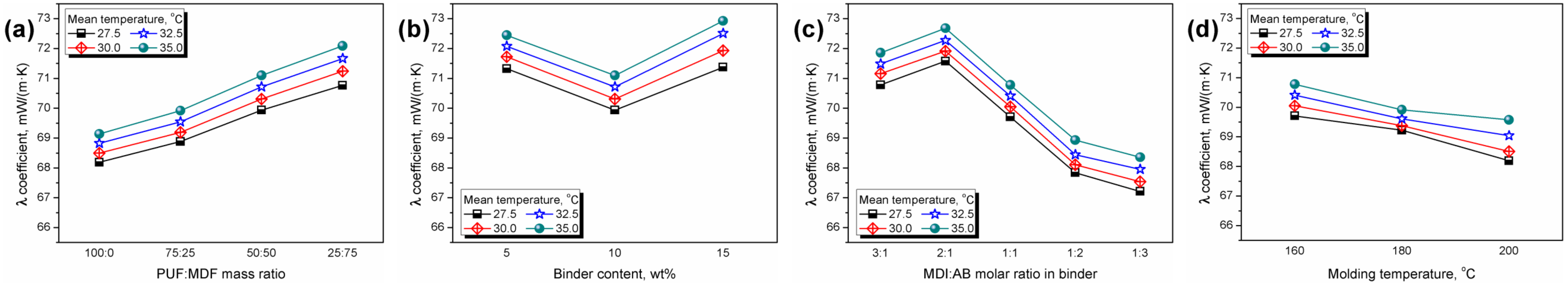
Analysis not possible, samples too fragile

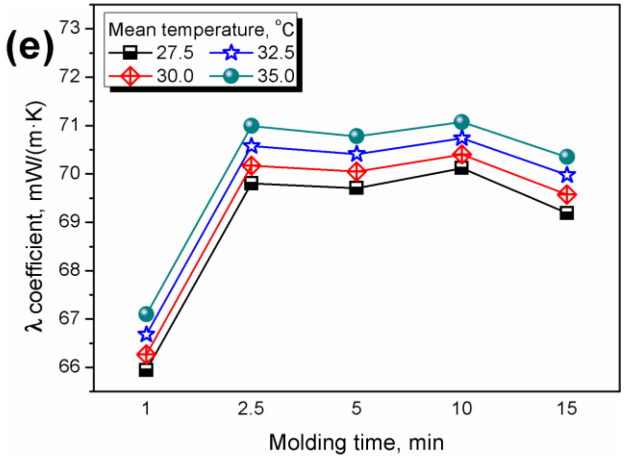






Composites thermal conductivity





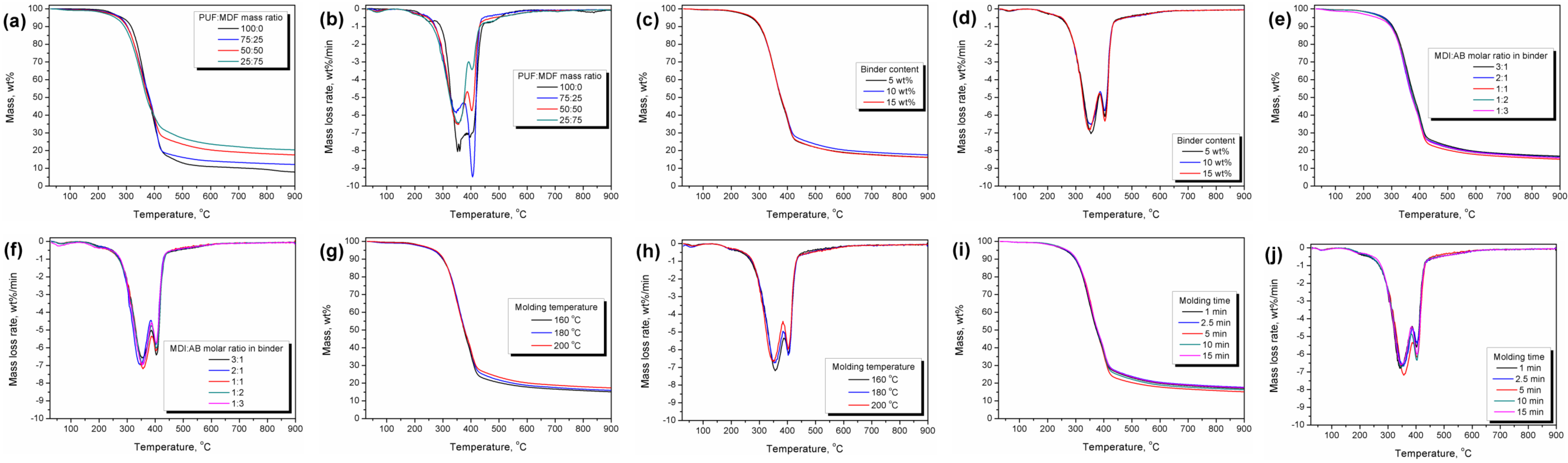
- PUFs’ cellular structure enhanced insulation performance
- Higher AB content in binder limited thermal conductivity
- Higher molding temperature slightly reduced thermal conductivity
- Hardly any impact of molding time was noted
- Conductivity changes aligned with porosity of material

Composites mechanical performance

Sample	Flexural strength, kPa	Deformation at flexural strength, %	Hardness, Sh0
1	-	-	51.3 ± 3.3
2	-	-	57.9 ± 4.5
3	204.7 ± 60.5	5.6 ± 1.1	76.8 ± 3.1
4	348.3 ± 71.6	1.6 ± 0.7	89.9 ± 3.8
5	61.9 ± 50.2	6.9 ± 1.7	72.1 ± 3.4
6	239.3 ± 47.6	3.9 ± 0.9	83.6 ± 4.0
7	232.7 ± 64.3	5.6 ± 0.7	81.7 ± 3.1
8	167.3 ± 14.6	5.5 ± 0.9	78.8 ± 3.9
9	153.7 ± 10.8	5.7 ± 1.1	75.1 ± 3.2
10	147.0 ± 4.5	5.4 ± 0.3	66.6 ± 3.3
11	95.1 ± 11.9	6.3 ± 1.9	62.7 ± 3.0
14	167.7 ± 11.1	5.1 ± 0.7	73.2 ± 2.9
15	195.0 ± 5.7	2.5 ± 0.7	67.2 ± 3.6
16	75.1 ± 6.3	5.5 ± 0.5	74.2 ± 4.0
17	164.5 ± 3.7	5.6 ± 1.5	76.2 ± 2.5
18	120.2 ± 4.3	6.9 ± 1.2	76.4 ± 2.7
19	77.7 ± 13.2	6.2 ± 1.3	65.2 ± 4.6

- Samples 1 and 2 – flexural test not possible
- Hardness mostly enhanced by MDF content and MDI loading
- Mechanical properties driven by the extent of PUF phase thermal decomposition

Composites thermal stability



- Higher MDF content increased char residue amount
- At the same time, decomposition onset shifted from 243 °C to 209 °C
- Higher binder content slightly enhanced thermal stability
- Excessive AB loading reduced thermal stability

Conclusions and future remarks

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

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Thank you!

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