

# Upcycling of wood and polyurethane foam wastes into composite materials

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## Introduction and motivation for the study



Fig. 1. Typical bulky wastes (left) and Circular Economy model (right).

- Municipal waste generation in EU Directives (Green Deal, Poland (in million tons): Climate Target Plan), 10.9 (2015) → 13.7 (2021)
- Only 40% of recycling level, Penalties for not meeting targets,
- Bulky waste – mainly wood, Growing environmental awareness, and polyurethane foams, Need for novel waste management methods, and proper applications,
- Lack of efficient management methods and proper applications, Need for final applications, Need for high-quality products.

## Materials and methods

Homogenization and densification – IdeaPro Intensive Mixer with star-belt type stirrer:

- (i) mixing of solids (30 s, 1000 rpm);
- (ii) pouring liquids (30 s, 250 rpm);
- (iii) intensive mixing (120 s, 1000 rpm);
- (iv) granulation (120 s, 200 rpm).

Final shaping – compression molding:

- (i) pre-pressing (4 min, 40 bar);
- (ii) molding (15 min, 180 °C, 20 bar, targeted density – 800 kg/m<sup>3</sup>).

Table 1. Material compositions applied in the presented study.

Component	1	2	3	4	5
	Content, wt%				
Oak chips	21.7		17.9		
Polyurethane foam waste	50.6		41.7		
Methylene diphenyl diisocyanate	6.6		5.4		
Ammonium bicarbonate	6.2		5.1		
Roflam P		15.0			
Expandable graphite	-	15.0	-	-	-
Exolit OP1312	-	-	15.0	-	-
Ammonium polyphosphate	-	-	-	15.0	10.0
Nanomer I28E	-	-	-	-	5.0



Fig. 2. Images of applied intensive mixer (left) and star-belt type stirrer (right).

## Results & conclusions

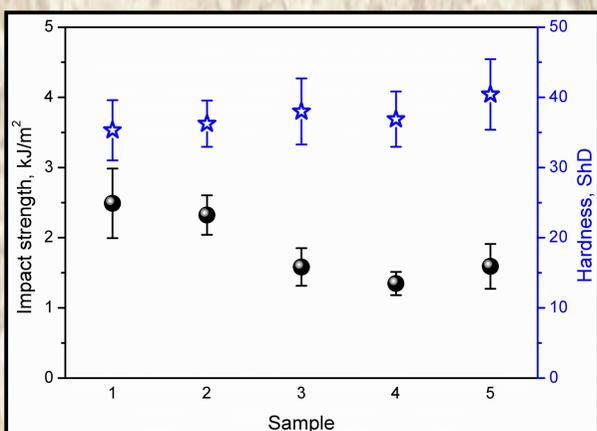
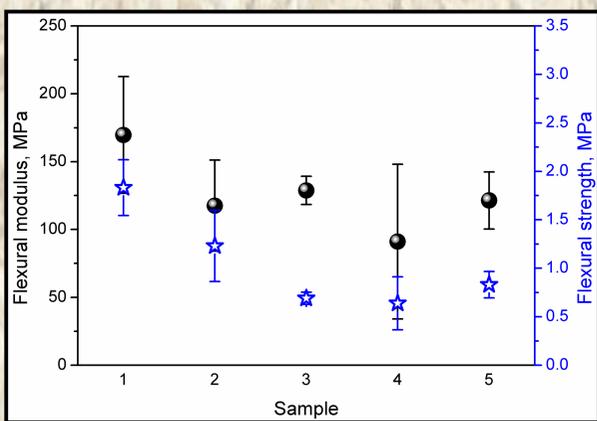
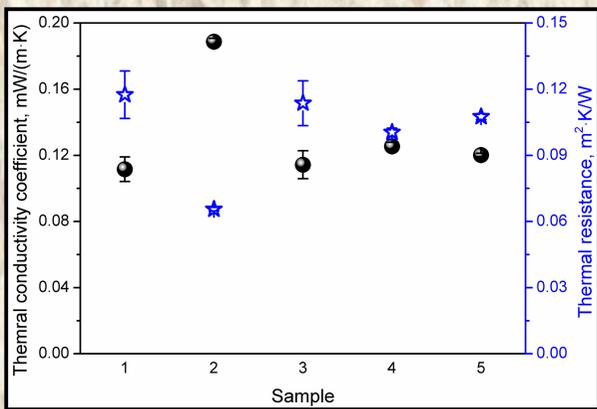


Fig. 3. The impact of applied material compositions on thermal insulation and mechanical properties of developed composite materials.

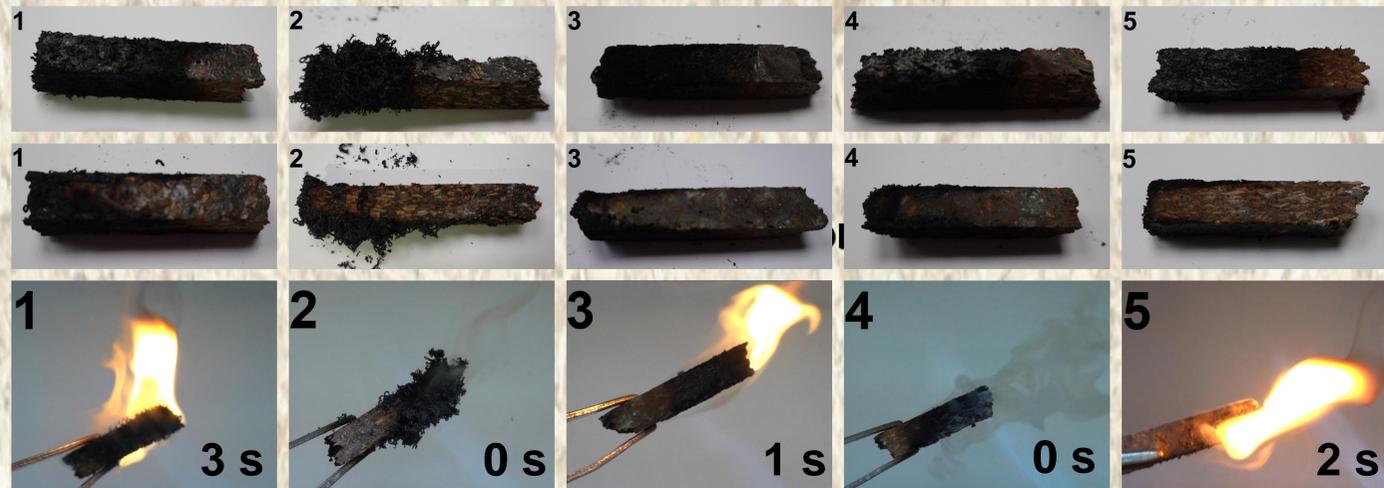


Fig. 4. Images of samples after 2x 20 s flame application (upper row); fire penetration depth (middle row); and images of samples directly after flame removal (after second 20 s fire application)

- Presented work highlights the potential for the manufacturing of composite materials from bulky wastes without the application of synthetic resins and with a minimal binder content (6.6 wt% of MDI), thanks to the presence of ammonium bicarbonate.
- Developed materials could be efficiently used in the construction and building sector for applications less demanding in terms of mechanical performance, which has been slightly deteriorated by the introduction of flame retardants.
- Flexural performance was hardly dependent on the applied flame retardants; a more significant impact was noted for impact strength and hardness, which have been related to the particle shape (flakes for graphite and spherical particles for other flame retardants) and origin of additives (organic or mineral).
- Introduction of expandable graphite significantly affected thermal insulation performance, which may limit the potential application range.
- Since applied polyurethane wastes already contained a portion of expandable graphite, the composite was self-extinguishing after flame removal; however, the fire penetration depth was the most significant among the analyzed materials.
- Application of all flame retardants or their compositions enabled efficient reduction of composites flammability, but their effects differed between samples; expandable graphite led to efficient intumescent effect, but caused sample fragmentation due to excessive loading; phosphorous-based additives enabled maintaining sample shape and formed efficient char layer, the most effectively for the application of montmorillonite (sample 5).



Fig. 5. Fragmentation of sample 2 due to the excessive expandable graphite loading.

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