Furan modified lignin: New sustainable pathway to the rigid polyurethane foams

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Introduction

Polymers

Synthetic Polymers

- Nylon
- Teflon
- Polystyrene
- Polyester
- Plastic

Natural polymers

- Cotton
- Wool
- DNA
- Protein
- Chitin
- Natural rubber
- Cellulose

Polyurethane

$$R{-}N{=}C{=}O + R'{-}OH$$

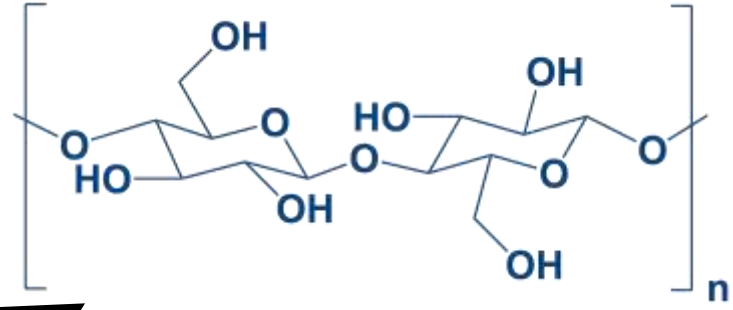
Poly-isocyanate + Polyol

Introduction

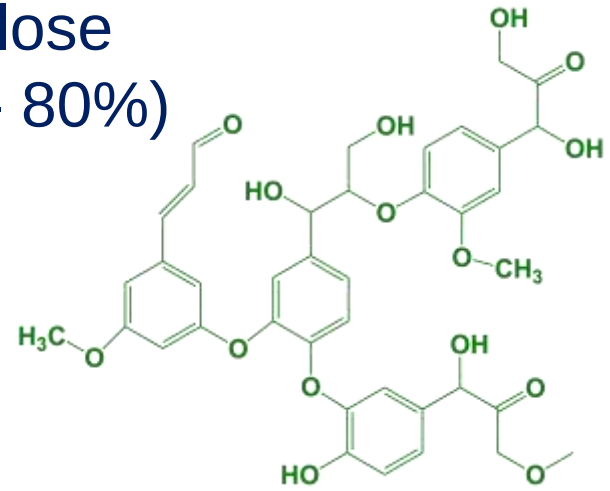
Incineration

Land filling

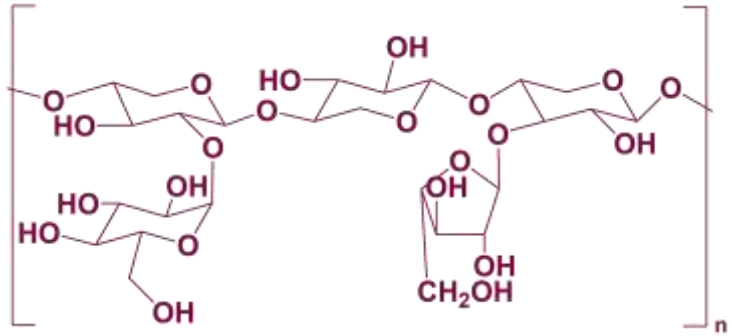
Animal feed



Cellulose
(9% - 80%)



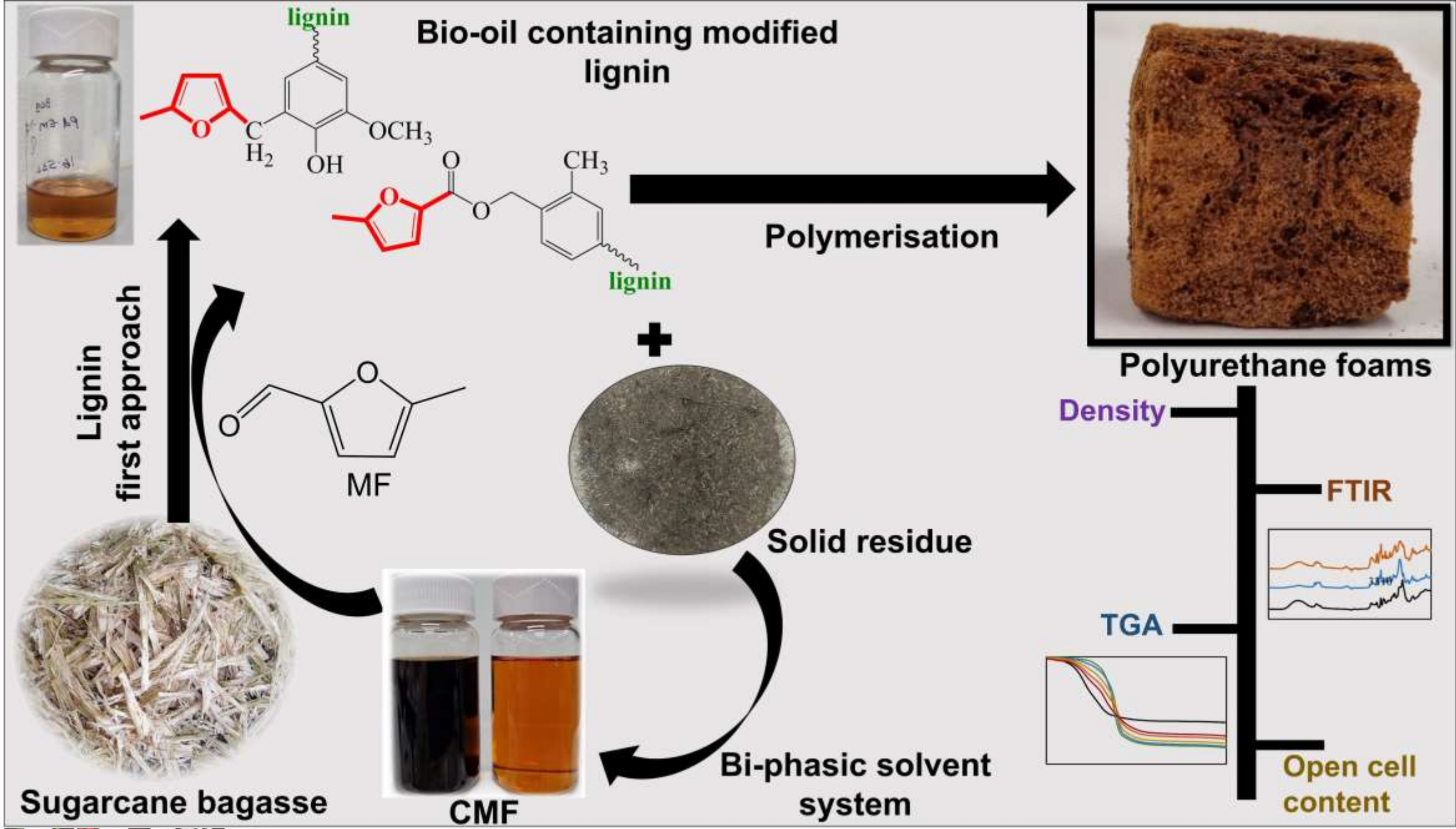
Lignin
(5% - 35%)



Hemicellulose
(10% - 50%)

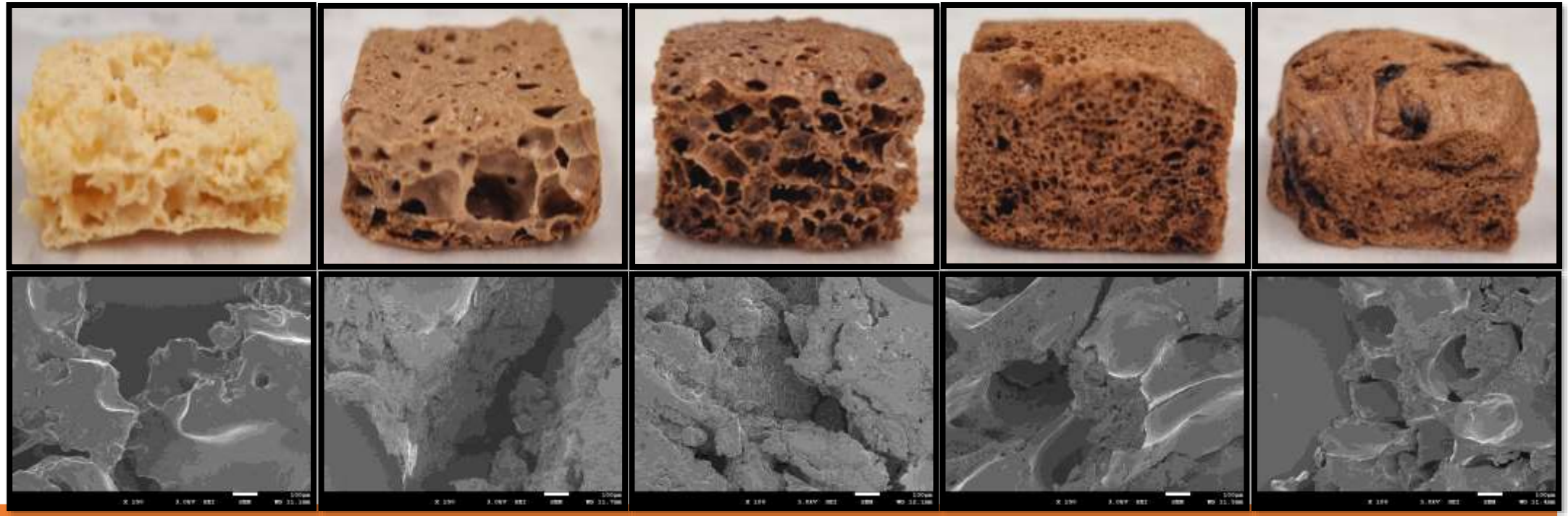
[1]agriculture.gov.au/agriculture-land/farm-food-drought/crops/sugar

OVERVIEW



CMF- 5(chloromethyl)furfural MF- 5-methylfurfural

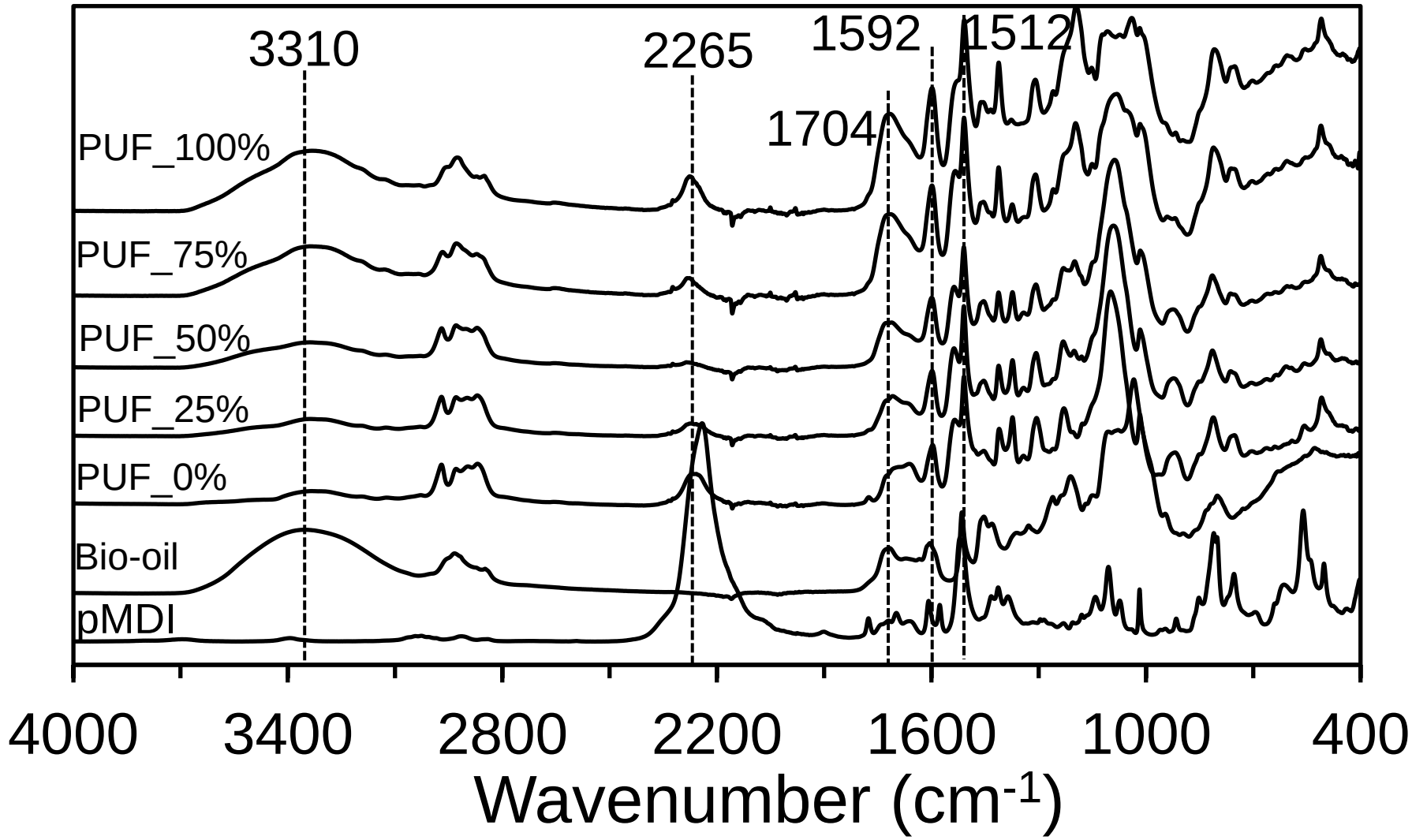
Morphology & structure of PUFs



Sample	PUF_0%	PUF_25%	PUF_50%	PUF_75%	PUF_100%
Density (g/cm^3)	0.419	0.411	0.232	0.200	0.292
Open cell content (%)	62	64	80	83	76

Reaction with Isocyanate?

- There is no remaining isocyanate at 50% bio-oil substitution. (~2265 cm^{-1})
- Shifted peak ~ 3300 cm^{-1} confirmed the N-H stretching vibrations from urethane bond.
- FTIR peaks related to the urethane linkage are:
  - 3310 cm^{-1}
  - 1704 cm^{-1}
  - 1592
  - 1512



Are those foams thermally stable?

The answer is YES!

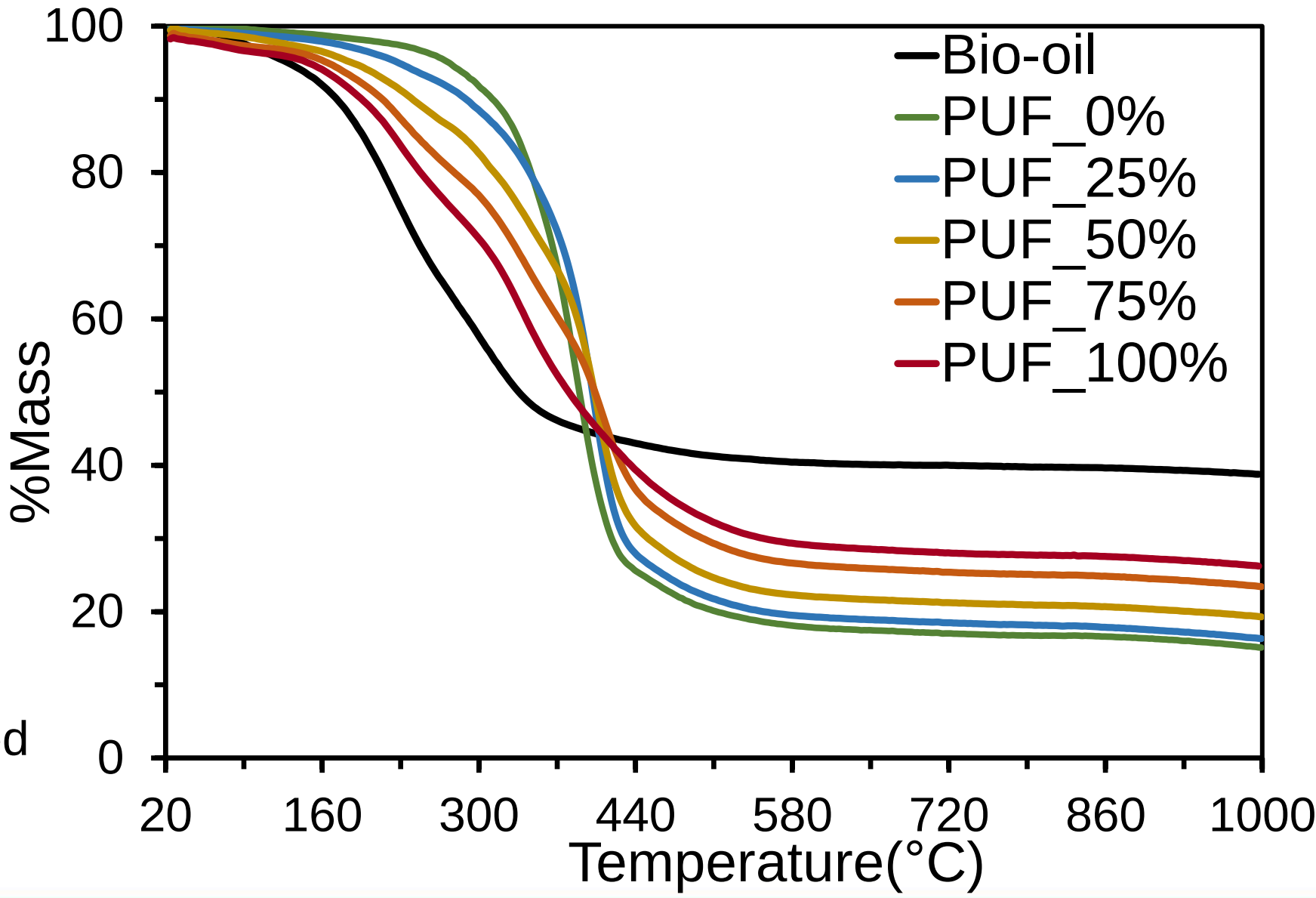
- Important temperature ranges:
  - 200 – 250 °C

Breakdown of C-N bond within urethane linkage

  - 320 – 460 °C

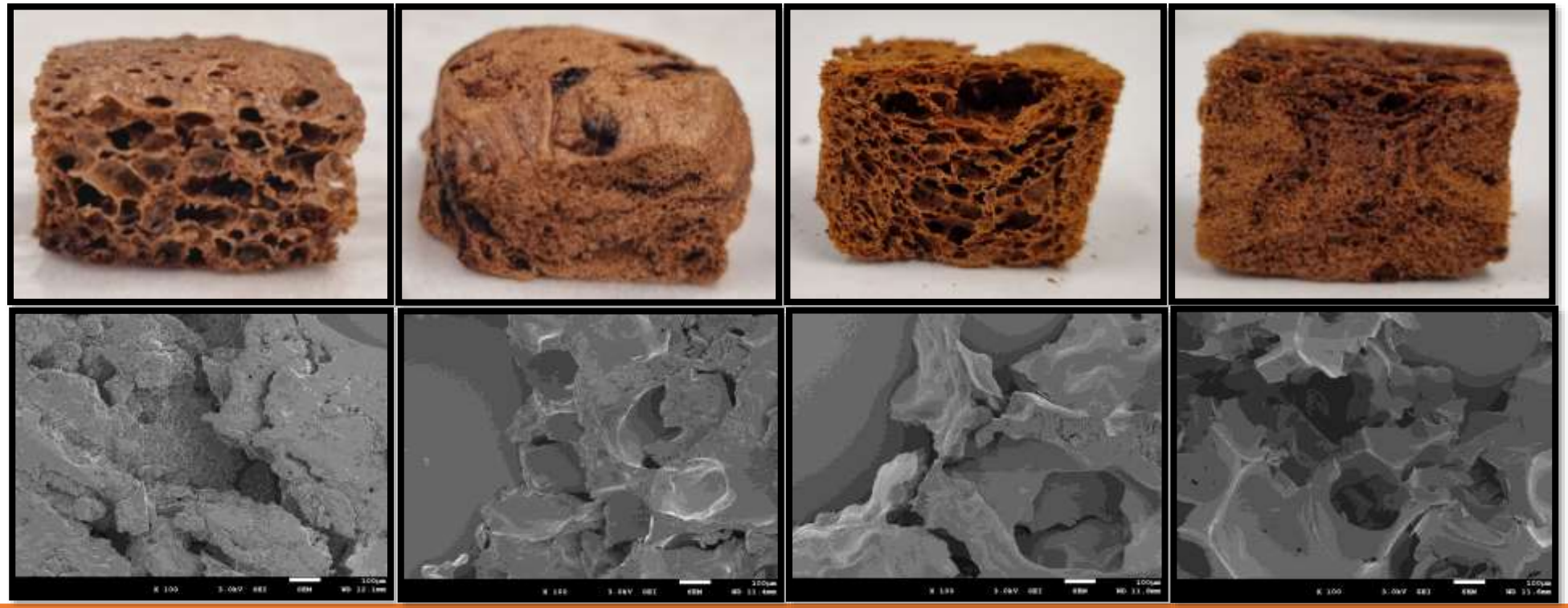
Decomposition of soft segments in PU foams

- ↑ bio-oil content - ↓ declined decomposition rate



MF-treated PUFs – Morphology & structure

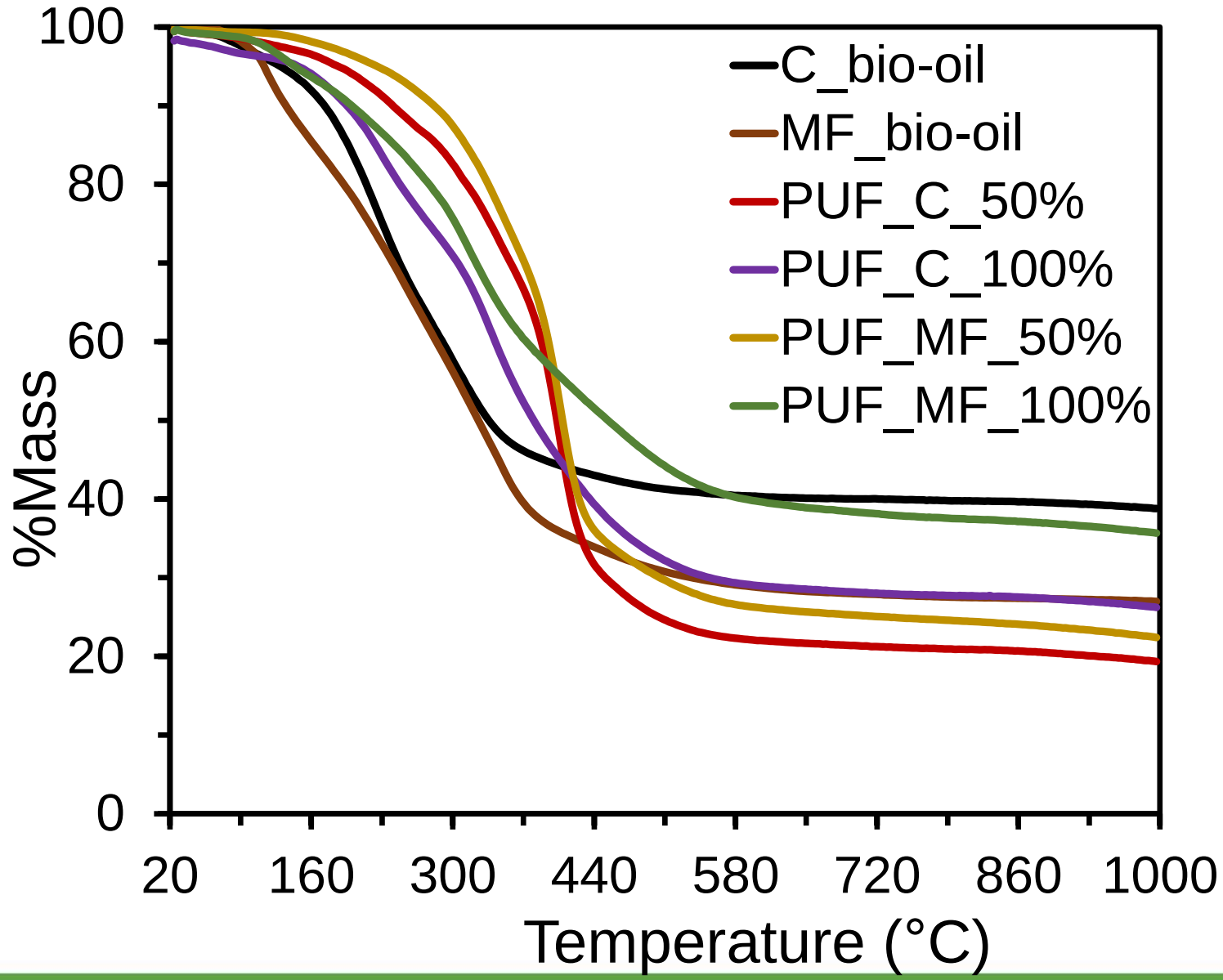
- With MF –
  - Dark in colour
  - Highly deformed structure
  - High number of open cells
  - Low density



Sample	PUF_C_50%	PUF_C_100%	PUF_MF_50%	PUF_MF_100%
Density (g/cm^3)	0.232	0.292	0.128	0.116
Open cell content (%)	80	76	89	91

MF-treated PUFs – Thermal stability

- Bio-oils & PU foams exhibit irreversible pattern of thermal stability
- 50% bio-oil separation has higher thermal stability than 100% bio-oil replacement
- MF treated PUFs contain low hydroxyl content which resulted in declined thermal properties



Conclusion

- Preparation of PU foams with lignin-rich bio-oil was successful even at 100% substitution.
- The added 5-methylfurfural (MF) had a greater effect on foam structure, morphology and density.
- Most of the foams can be described as open cell foams with > 80% open cell content.
- High amount of open cell content makes them more suitable as sound absorbing materials.
- Overall, 50% bio-oil substitution demonstrated the best PU formulation.

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Thank you!