Recyclable-by-design polyurethane polymer via dynamic covalent bonds

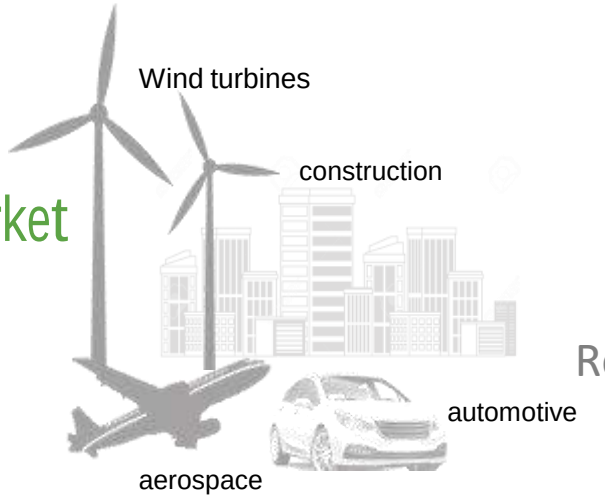
Donya Ramimoghadam

CERC Research Fellow

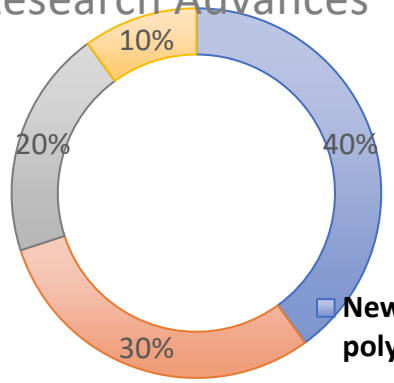
CSIRO (Manufacturing Business Unit)

Introduction

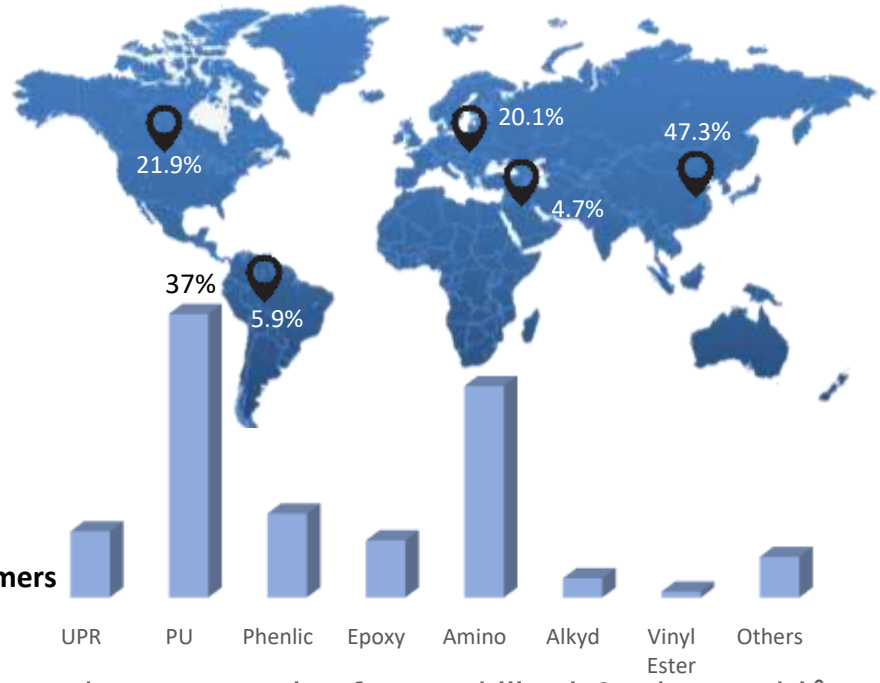
- Thermoset polymers market
- Circular Economy
- Sustainable recycling of Polyurethane
- Recyclable-by –design approach
- Dynamic Covalent bonds



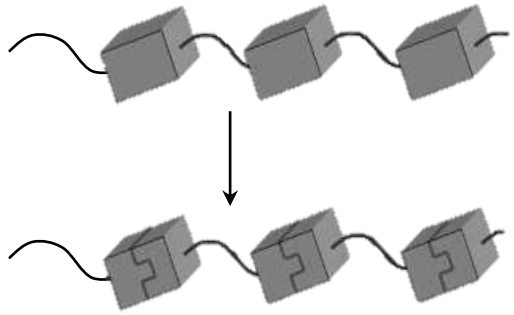
Research Advances



Global Thermosetting Plastics Market, by region and type 2022 [1]

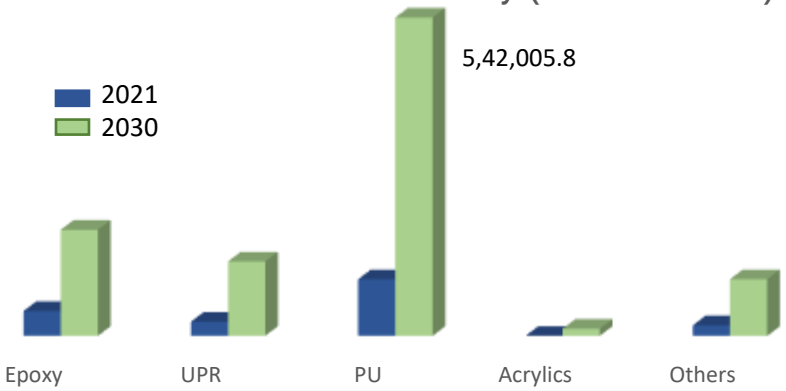


Conventional polymer



Dynamic covalent incorporated polymer

Thermoset Market for e-mobility (USD Thousands)[2]

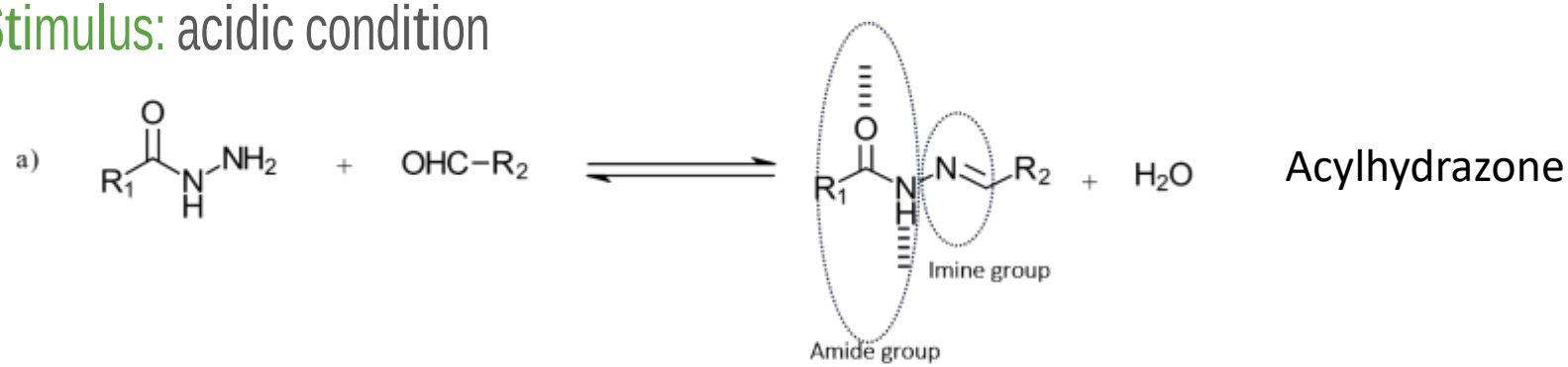


Sources: [1]Coherent Market Insights, and [2]Global Market Insight, WWW.gminsights.com,

Dynamic Covalent Bond

Dynamic covalent Bonds: Hydrazone/Acylhydrazone

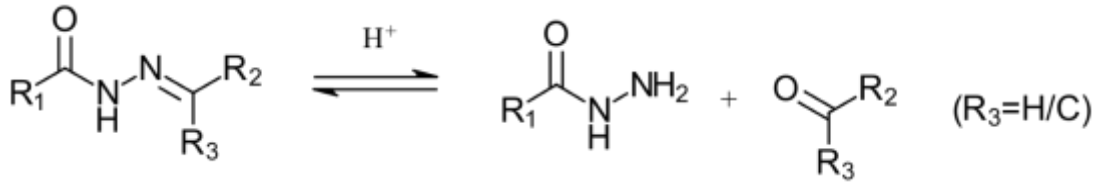
Stimulus: acidic condition



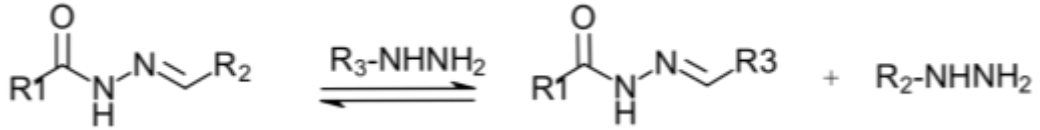
Acylhydrazone

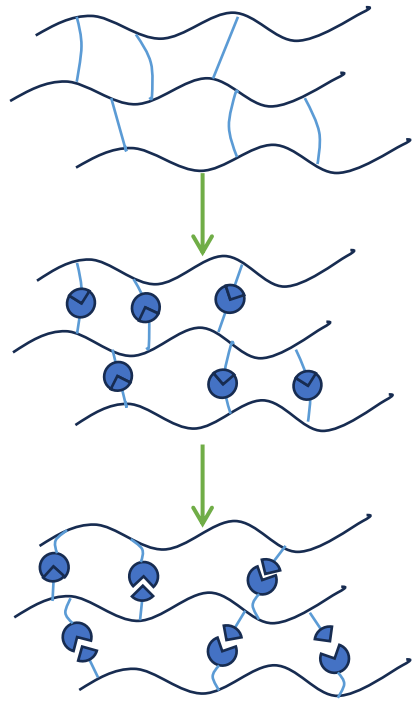
Hydrazone

Reversible



Exchange reaction

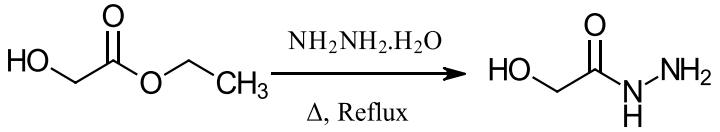




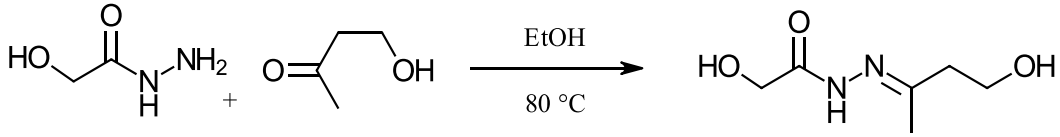
Design and synthesis of Model Compound

PU synthesis

Diol incorporated with acylhydrazone linkage

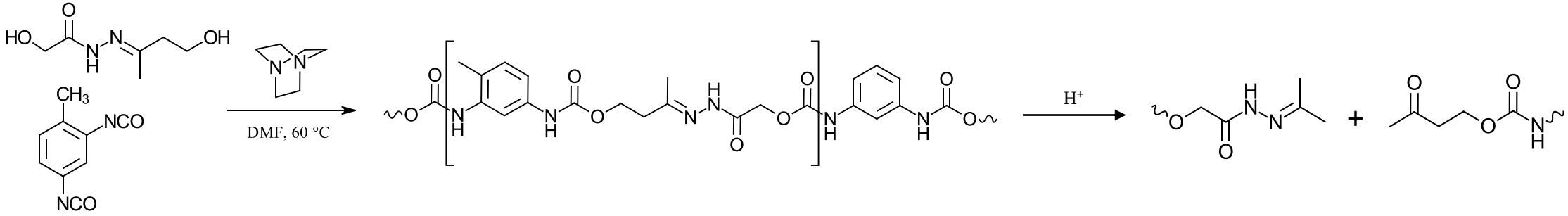
1) 

Ethyl Glycol Hydrazide

2) 

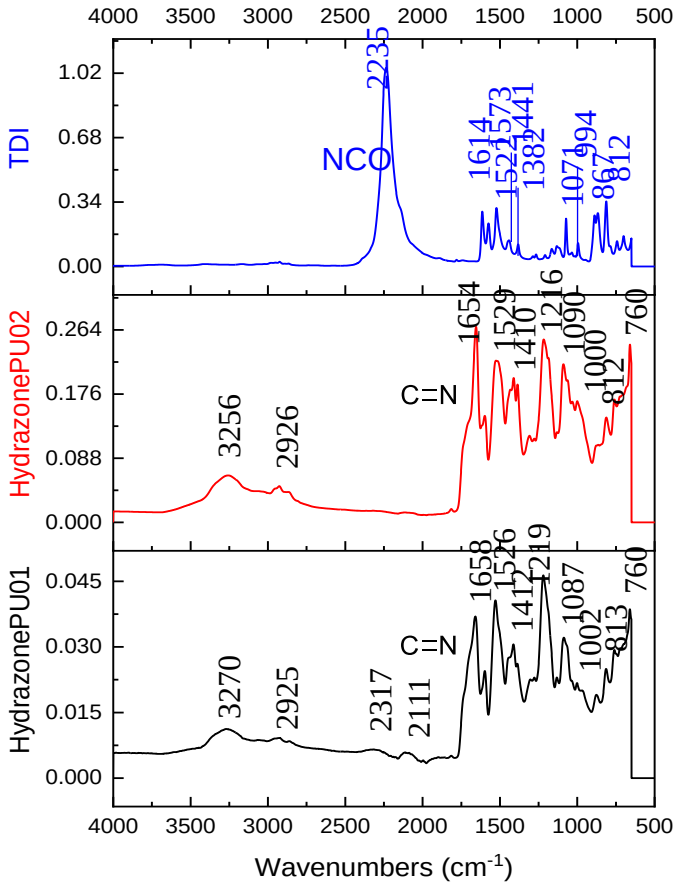
Hydrazone Diol

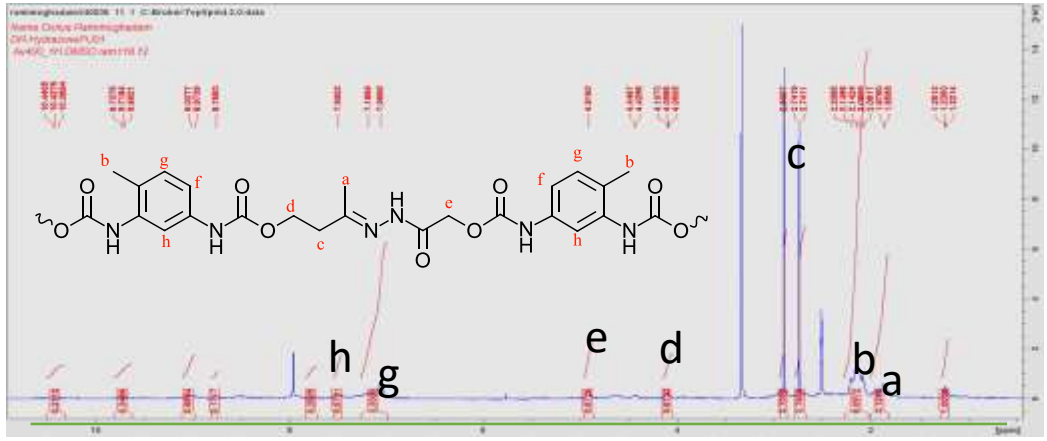
PU synthesis with acylhydrazone-incorporated diol

3) 

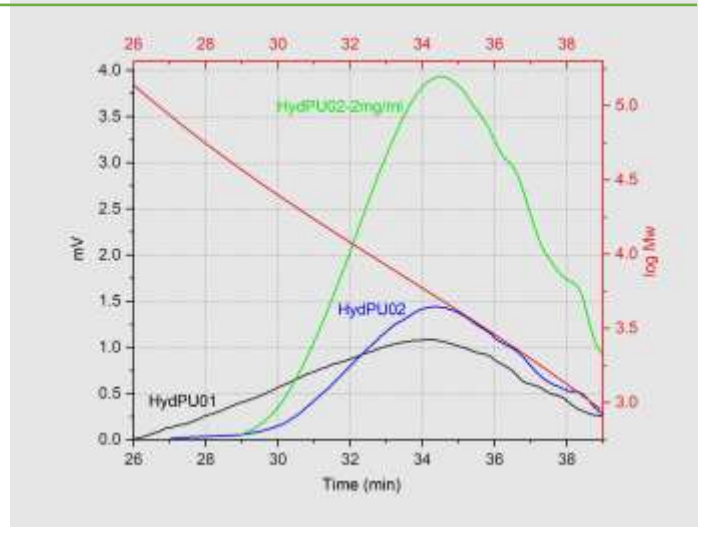
Characterisation of Model Compound

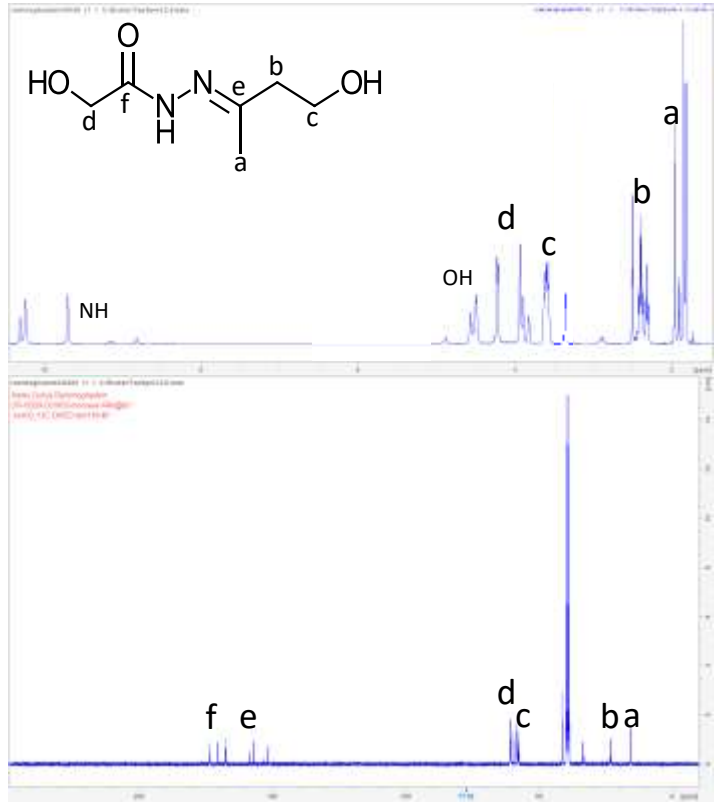
NMR/FTIR/GPC results

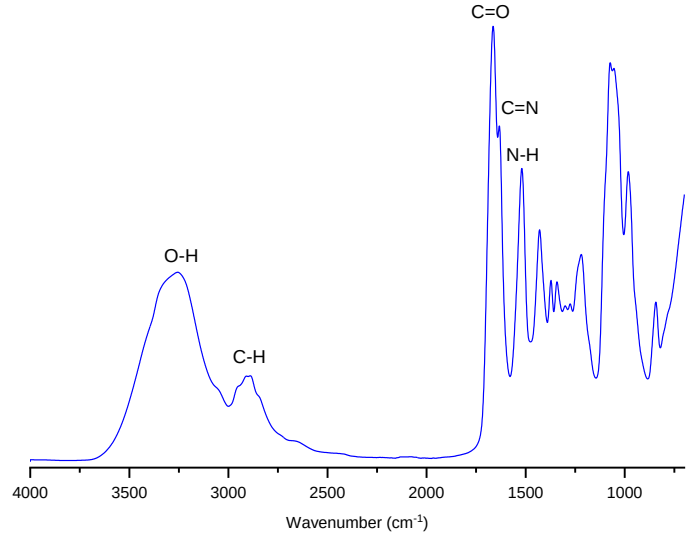




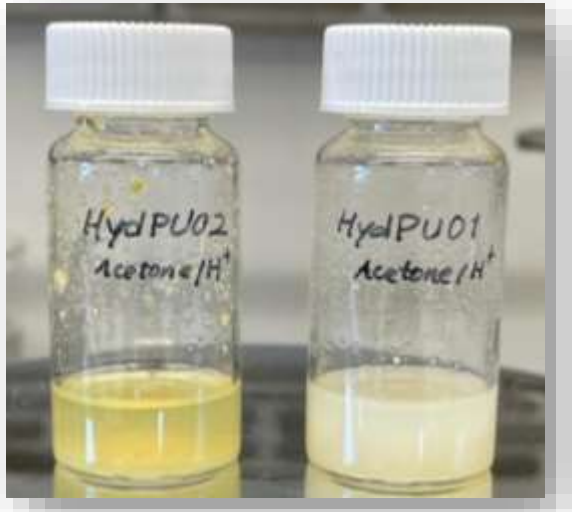
Polymer	Mw	Mn	Mz	Mw/Mn	Mz/Mw
HydPU01	13125	5522	30884	2.3	2.3
HydPU02	6334	3854	9725	1.6	1.5





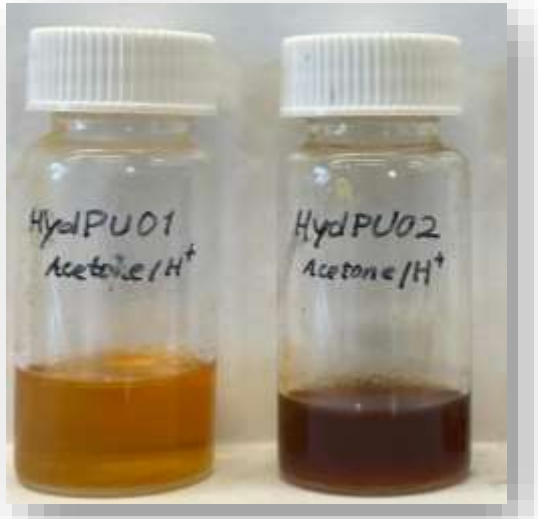


Depolymerisation test of Model Compound



Depolymerise in Acetone/H^+

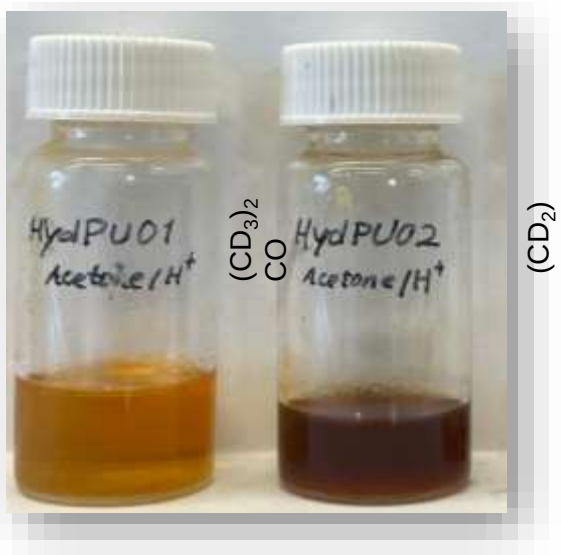
Heated at 60 °C, Overnight

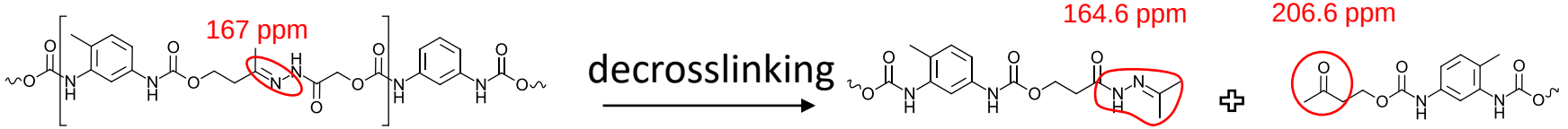


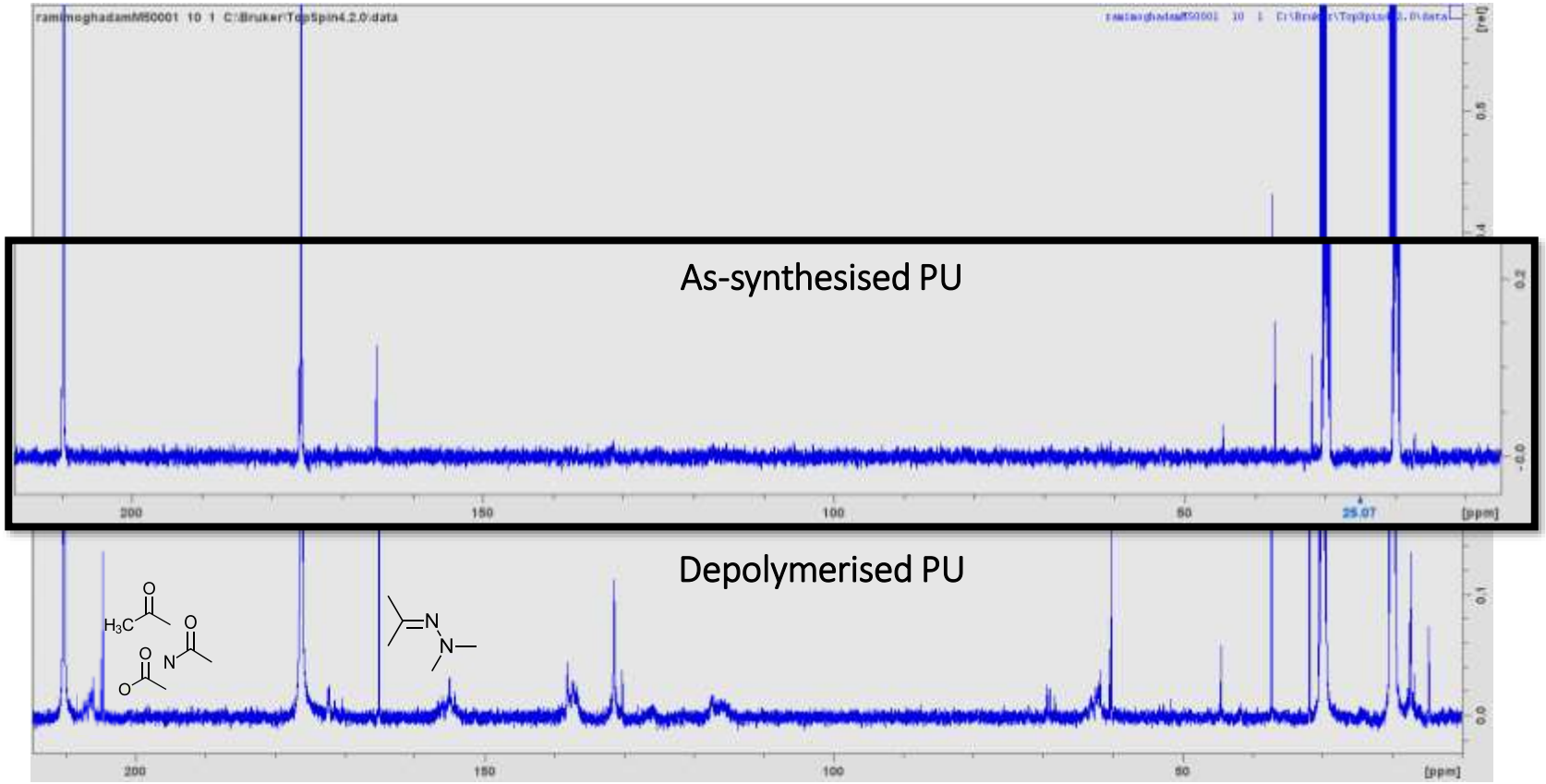
HydPU,
60 °C, 15 mins

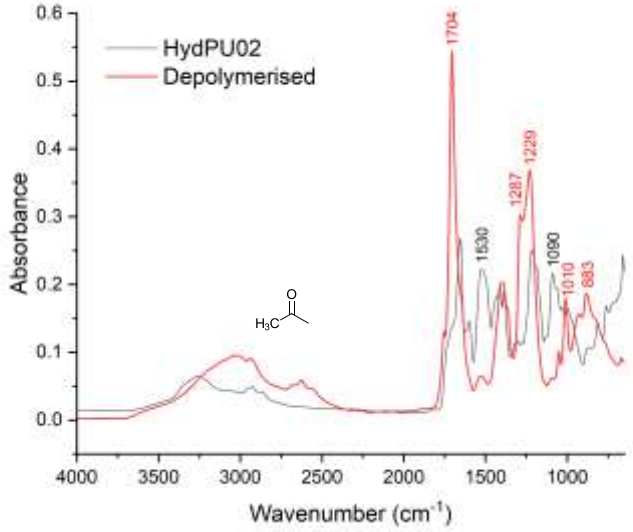
HydPU,
60 °C, 30 mins

Depolymerisation test of Model Compound

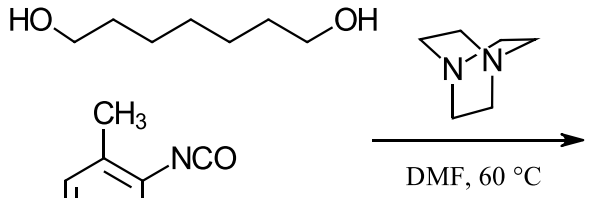


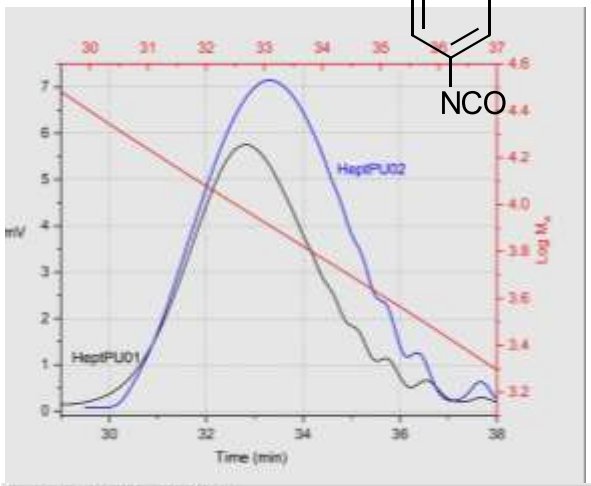


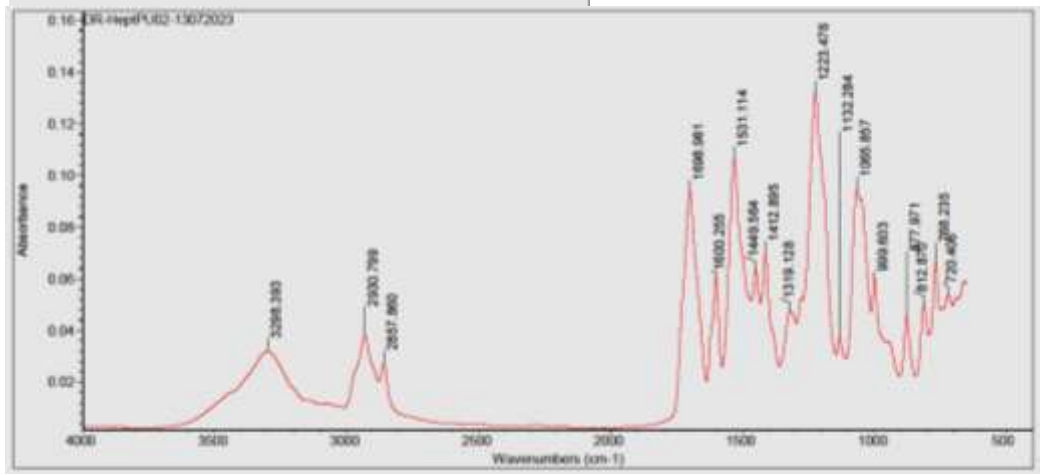


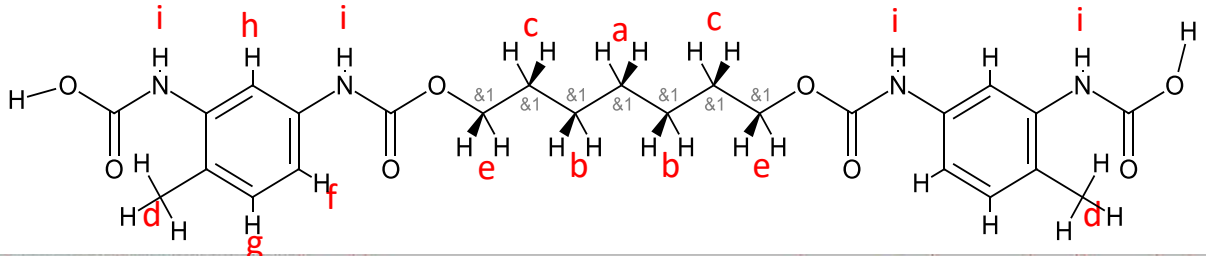


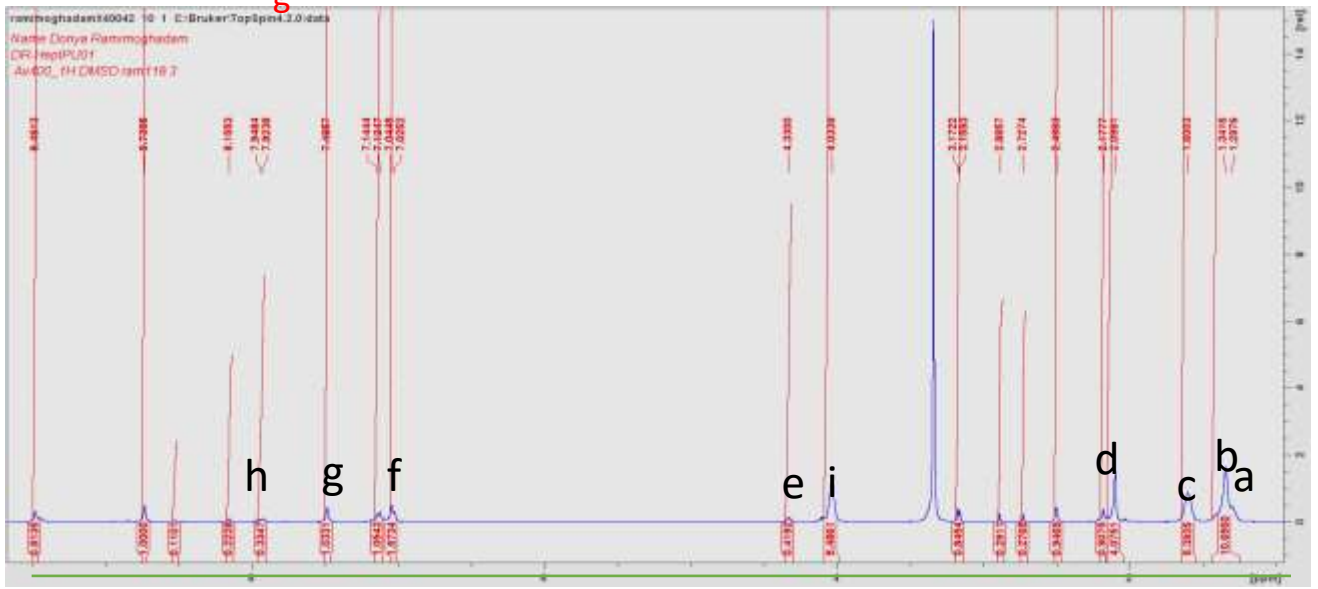
Control Compound synthesis and characterisation









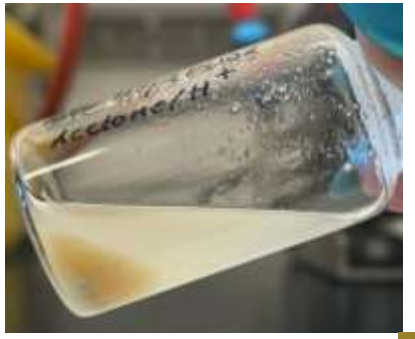


Polymer	Mw	Mn	Mz	Mw/Mn	Mz/Mw
HeptPU01	9045	7320	10849	1.2	1.2
HeptPU02	8030	6473	9735	1.2	1.2

Depolymerisation test of Control Compound

Heated at 60 °C, Overnight

Acetone/H^+



HeptPU

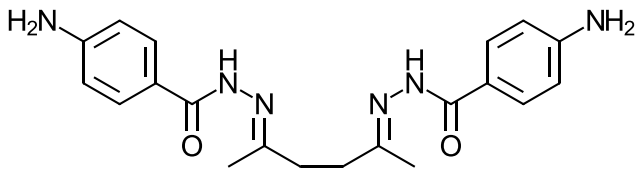
15 mins

30 mins

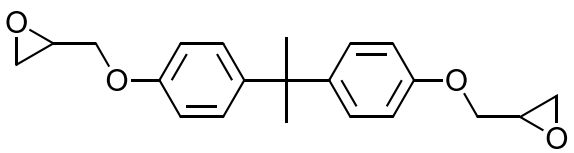
180 mins

HydPU

Acylhydrazone-incorporated Epoxy

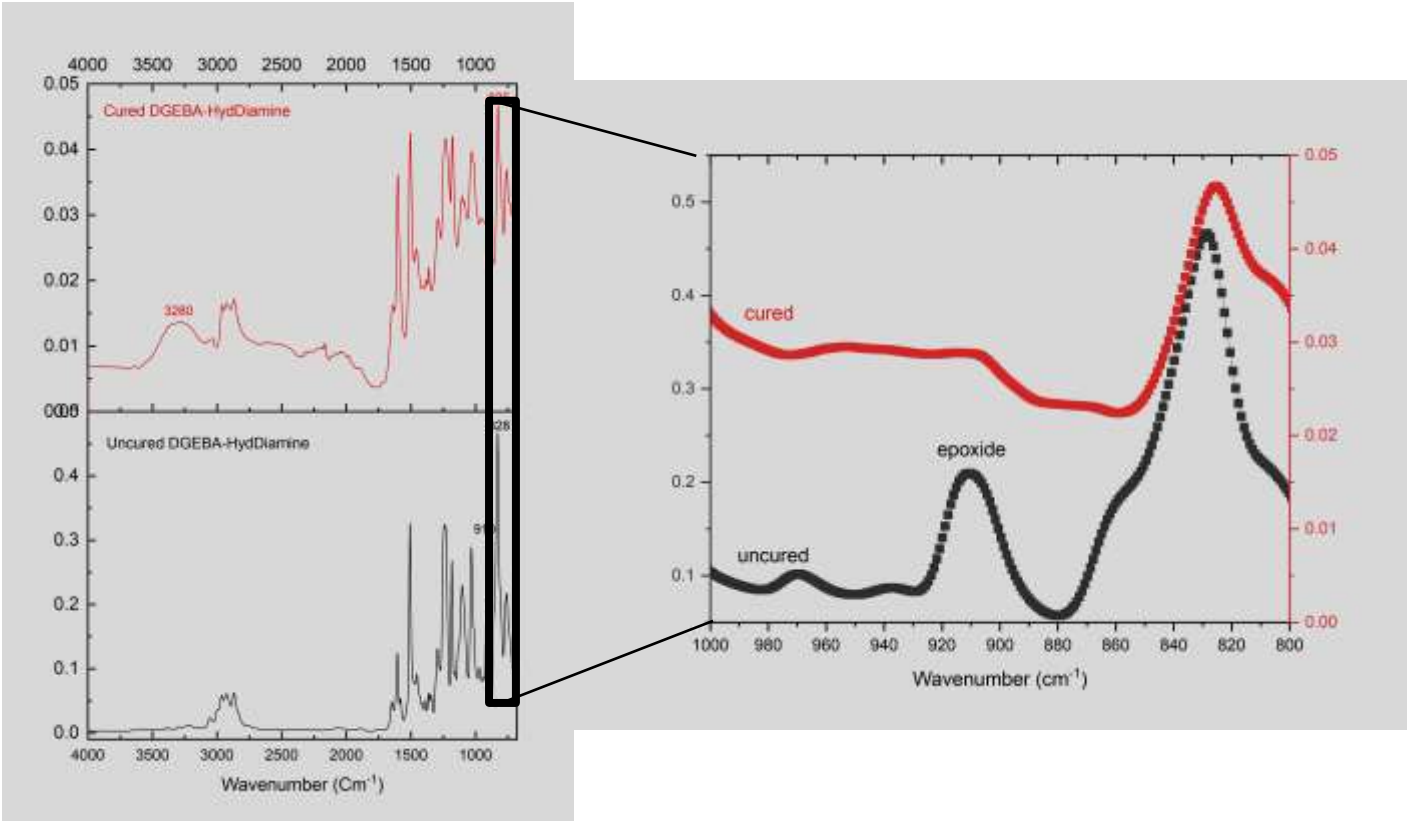


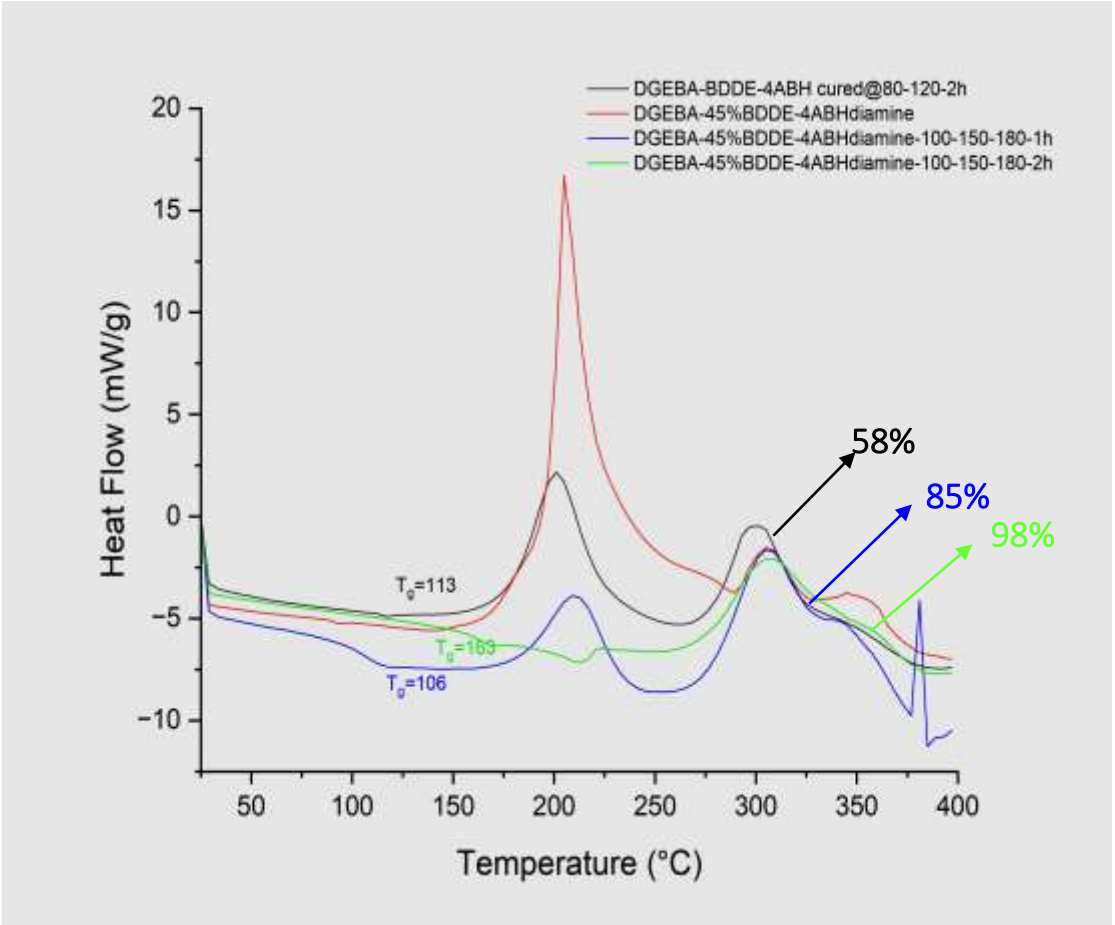
+



DGEBA (Diglycidyl Ether Bisphenol A)

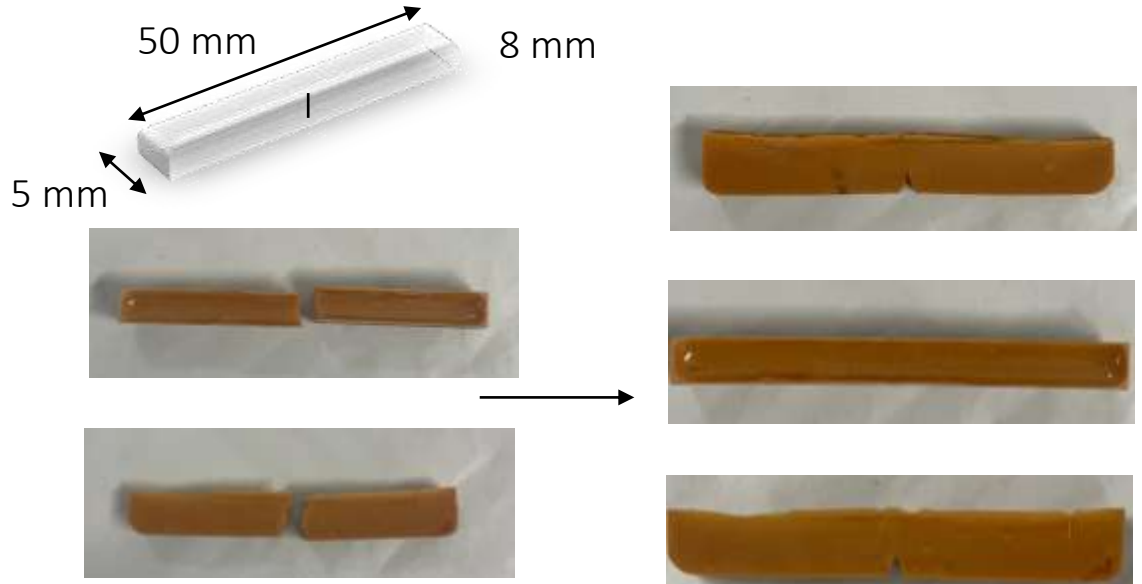
curing →





Dynamic property test on HydEpoxy

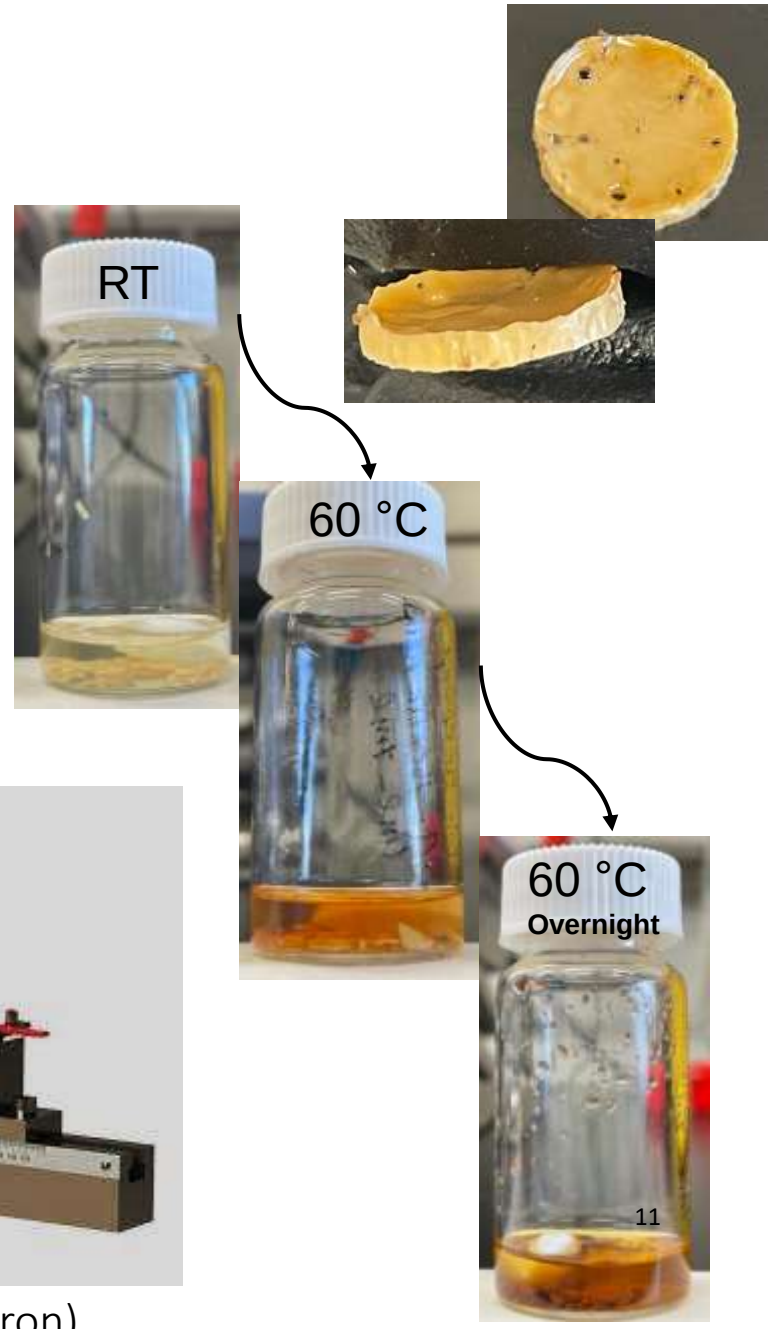
Flexural test (Single-Edge Notched Beam (SENB) Test)



Fractured cured DGEBA/HydDA

Heated cured DGEBA/HydDA at 140°C

SENB test (Instron)



Conclusion

1. Formulation of linear PU model compound with hydrazone crosslinker
2. Synthesis and characterisation of linear PU model compound
3. Depolymerisation test of linear PU model compound
4. Synthesis, characterisation and depolymerisation of control polymer
5. Formulation, synthesis and characterisation of hydrazone-incorporated epoxy

Acknowledgement

Polymer Interface and composite Group

Ranya Simons

Richard Evans

Graeme Moad

Susan Holmes

Almar Postma

Melissa Skidmore